SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Sludge Elutriation—Torpey and Lang

Rating of Porous Diffusers—King

1951 Industrial Wastes Forum

Algae Control Studies—Fitzgerald, et al.

JULY, 1952—VOL. 24, No. 7

Make Plans to Attend

SILVER ANNIVERSARY MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

IN CONJUNCTION WITH

NEW YORK SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

HOTEL STATLER
NEW YORK CITY

October 6-9, 1952

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS
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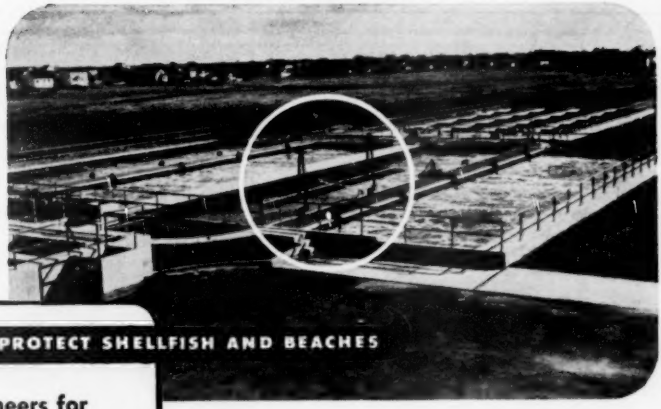

TO PROTECT SHELLFISH AND BEACHES

Engineers for
FAIRFIELD, CONN.
Choose
CHICAGO
AIR-DIFFUSION
SYSTEM

Aeration Tanks, Fairfield, Connecticut Sewage Treatment Plant, with Chicago Swing Diffusers and Precision Diffuser Tubes. Air is supplied by three Chicago Standardaire Blowers. Two Blowers are direct connected to electric motors and have a capacity of 2000 cfm each at 6.5 psi. One Blower is direct connected to a gas engine and has a capacity of 2100 cfm at 6.5 psi. Design flow of the plant is 4 M.G.D. Bowe, Albertson & Associates, Engineers.

The City of Fairfield, Connecticut, is assured of continuous and economical operation of the aeration battery in their new Activated Sludge Sewage Treatment Plant. Bowe, Albertson & Associates, Engineers, specified a Chicago Air Diffusion System to provide complete equipment for sewage aeration. Everything necessary from air to water is specifically designed and engineered as a unit to treat sewage and industrial wastes. The Chicago Standardaire Blower, Swing Diffusers and Precision Diffuser Tubes provide efficient, quiet, continuous operation at low cost. Over 100 Chicago Air Diffusion Systems have been specified or installed in Sewage Treatment Plants.

Other Chicago Sewage Equipment makes possible the most economical and efficient operation of the plant. Two Chicago Comminutors cut coarse sewage matter into small settleable solids without removal from the channel. One 10″ and two 8″ Chicago Vertical Open Shaft Non-Clog Pumps handle the raw sewage. Everything was done to provide the City of Fairfield with a Sewage Treatment Plant that would deliver a clear, sparkling effluent. Shellfish beds in Long Island Sound and the recreational aspects of the surrounding waters will not be contaminated.

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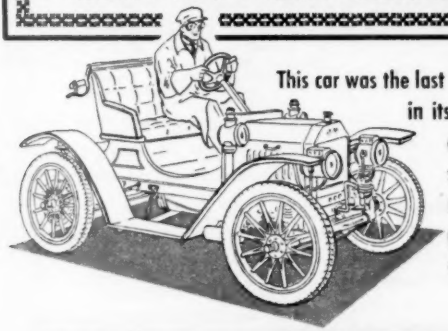

This car was the last word in transportation . . . in its day. But would you buy one for use on today's super highways? Certainly not. Then why buy chlorine gas feeders of yesterday's design?

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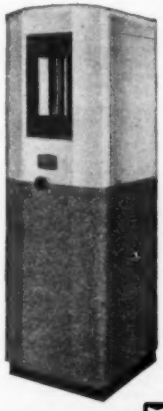

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FLOW CONTROL NOTES

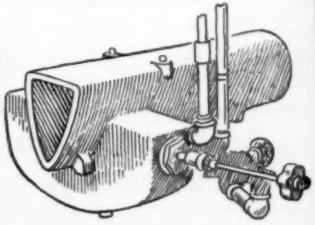
Measuring Open Flow of Raw Sewage

Problem: to measure raw sewage flowing from 24" main, under gravity head only, under open flow condition at outfall.

Analysis: Minimum measurable head; wide flow range...maximum to 5% of max; top flow high. Measuring device to be non-clogging, self-scouring. Measurements to be transmitted several hundred yards. Venturi tube ruled out by low pressure - flow nozzles by clogging liquid.

Solution: Simplex "S" parabolic flume and "H" meter met all requirements...meter could be remotely located by use of Simplex electric transmission system.

Result: where most standard measuring devices could not be used, "S" flume and "H" meter provide accurate measurements over long flow ranges.



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Association	*Place*	*Time*
Pennsylvania Sewage and Ind. Wastes Association	Pennsylvania State College, State College, Pa.	Aug. 27–29, 1952
Kansas Sewage Works Assn.	University of Kansas, Lawrence, Kans.	Sept. 3, 1952
Iowa Sewage Works Association	Grinnell College, Grinnell, Iowa	Sept. 9–11, 1952
Rocky Mt. Sewage Works Assn.	Frontier Hotel, Cheyenne, Wyo.	Sept. 15, 1952
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Andrew Johnson Hotel, Knoxville, Tenn.	Sept. 15–17, 1952
South Dakota Water and Sewage Works Conference	St. Charles Hotel, Pierre, So. Dakota	Sept. 17–19, 1952
German Sewage Technologists Assn.	Weisbaden, Germany	Sept. 17–20, 1952
Mo. Water and Sewerage Conference	Governor Hotel, Jefferson City, Mo.	Sept. 21–23, 1952
Georgia Water and Sewage Association	Georgia Inst. of Technology, Atlanta, Ga.	Sept. 24–26, 1952
West Virginia Sewage and Industrial Wastes Assn.	Chancellor Hotel, Parkersburg, W. Va.	Oct. 3–4, 1952

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New York Sewage and Industrial Wastes Association
Hotel Statler, New York City
October 6–9, 1952

Pacific Northwest Sewage and Industrial Wastes Assn.	Multnomah Hotel, Portland, Ore.	Oct. 23–24, 1952
The Canadian Institute on Sewage and Sanitation	Seigniory Club, Montebello, Que.	Nov. 3–5, 1952
North Carolina Sewage and Industrial Wastes Assn.	Skyland Hotel, Hendersonville, N. C.	Nov. 10–12, 1952
Florida Sewage and Industrial Wastes Association	San Carlos Hotel, Pensacola, Fla.	Nov. 16–19, 1952

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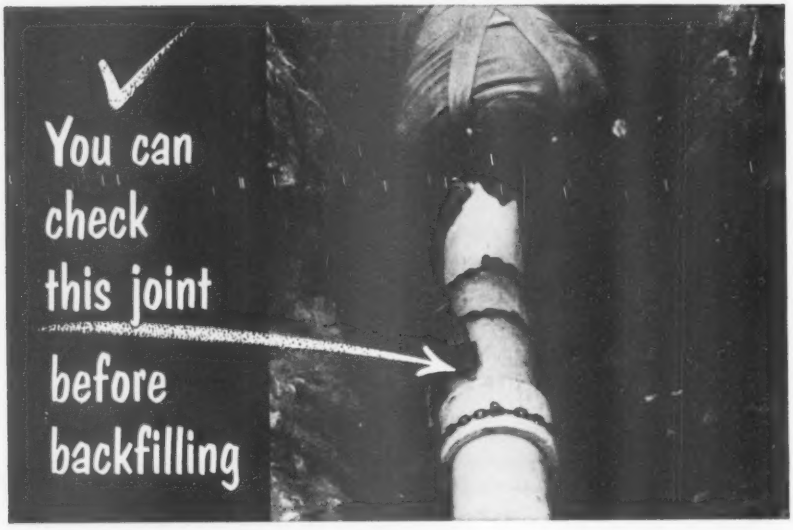

...it's the tight RING-TITE JOINT used with TRANSITE SEWER PIPE

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This "packaged" joint . . . furnished with Transite Pipe and ready for assembly—has still other, important practical advantages. Not only are there fewer joints to make, due to long 13′ lengths, but time is saved also by eliminating the use of poured compounds. Just a simple assembly operation with a mechanical coupling puller, and the Ring-Tite Joint is correctly placed and ready for service.

Its tightness means less over-all infiltration in the sewerage system and this effects savings in treatment costs. Transite's high flow capacity (Manning's $n = .010$) often results in substantial installation savings by permitting flatter grades and shallower trenches . . . a particularly important economy where pipe is laid at or below the ground water table or in rock excavation.

For further data about this corrosion-resistant asbestos-cement pipe and how it can save money in your sewerage system, write for Folder TR-103A. Address your inquiry to Johns-Manville, Box 60, New York 16, N. Y.

JM Johns-Manville TRANSITE SEWER PIPE

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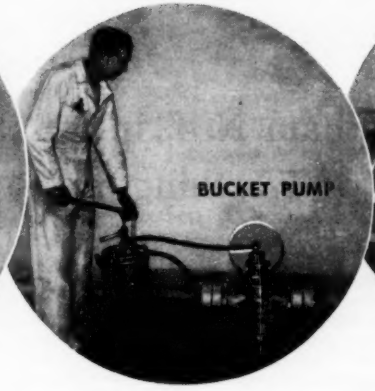
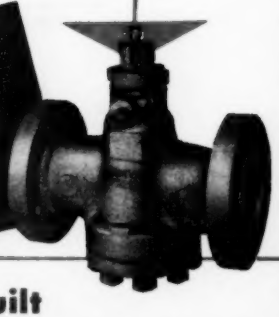
A COMBINATION LUBRICANT SCREW AND GIANT BUTTON HEAD FITTING

NOW Nordstrom Hypreseal Valves Can Be Lubricated *WITHOUT INTERCHANGING PARTS* By These Three Methods . . .



To meet the growing demand for hand gun and bucket pump lubricating equipment, Rockwell Manufacturing Company has developed a new fitting for Nordstrom Hypreseal valves which is adaptable to any method of lubrication. Now furnished at no additional charge with all Nordstrom Hyperseal valves, the new fitting eliminates the bother and cost of purchasing giant button head fittings for hand gun or bucket pump lubrication. The new Rockwell fitting is also available as a separate unit to replace the lubricant screw on Nordstrom Hypreseal valves now in service. For further information contact your Nordstrom representative or write to Rockwell Manufacturing Company, 400 North Lexington Ave., Pittsburgh 8, Pa.

Now Standard Equipment on all Nordstrom Hypreseal Valves



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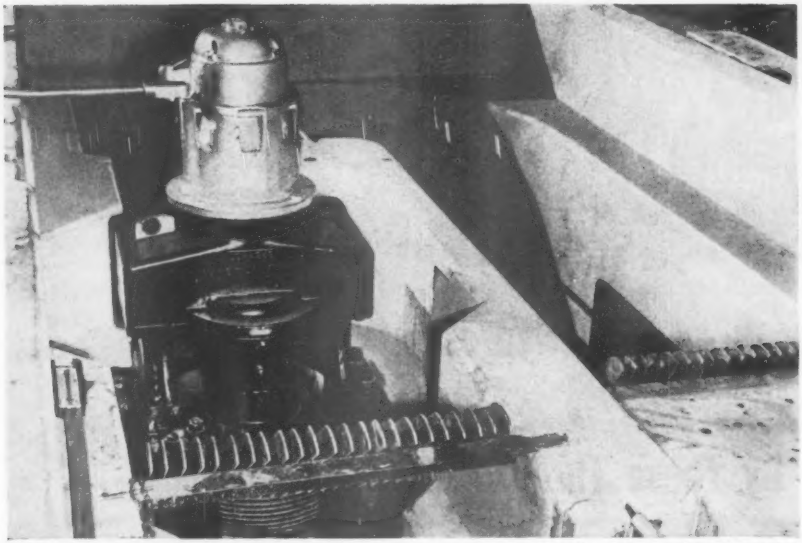

WORTHINGTON COMMINUTOR IS EASILY INSTALLED TO HANDLE LARGE VARIATIONS IN FLOW like this one at the Madison-Chatham (N. J.) Sewage Treatment Plant. Maximum wet-weather flows are occasionally as high as five times the average design dry-weather flow. An overflow screen is installed on top of the comminutor to screen flows in excess of the comminutor's capacity. Screenings are later raked down into the comminutor during period of normal flow. The overflow screen makes the comminutor independent of the by-pass on right which may later be used as a channel for a second comminutor. Plant Superintendent is Edward P. Molitor.

Madison-Chatham, N. J., installation proves adaptability of Worthington COMMINUTOR

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- It can be readily installed in new or existing straight-flow rectangular channels.
- Cutter-racks are quickly removable for sharpening or replacement.
- It may be flooded without damage because it's protected by a mercury seal.

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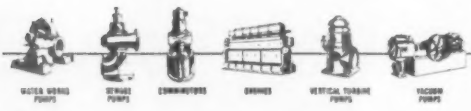
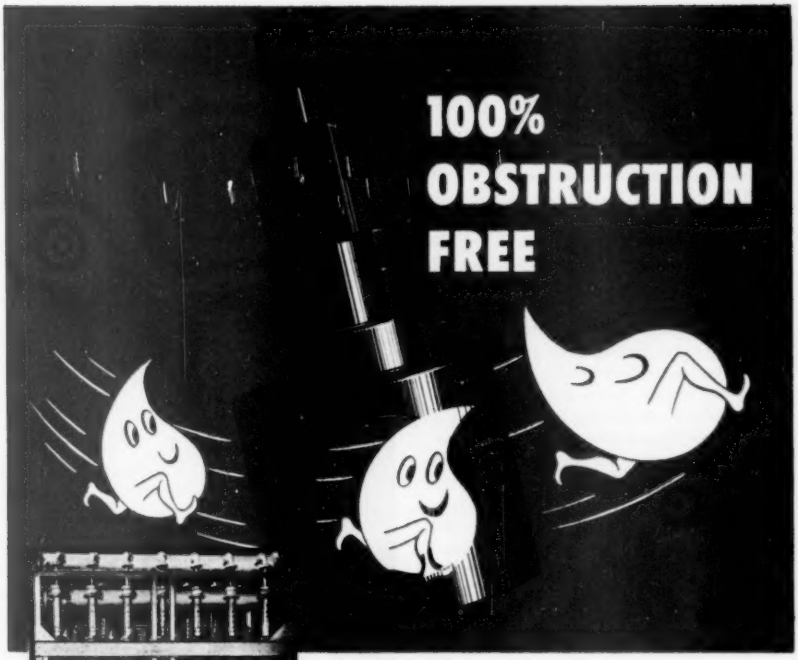
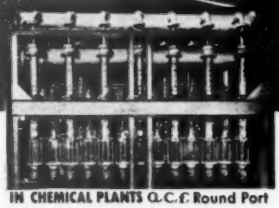


All Major Public Works Equipment Under One Responsibility

WORTHINGTON

Public Works Equipment





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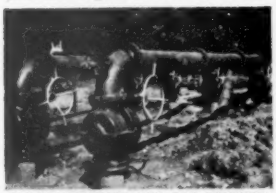

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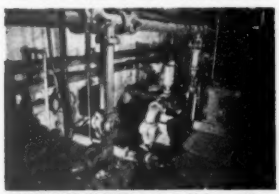

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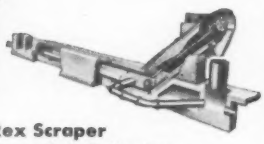

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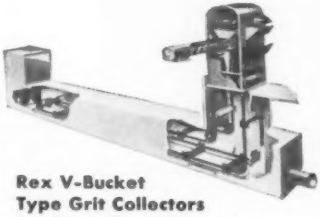

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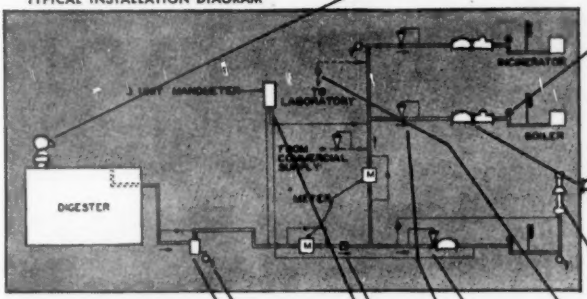

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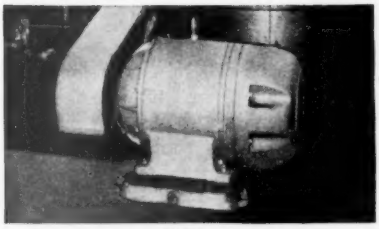

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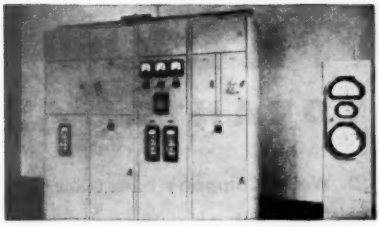

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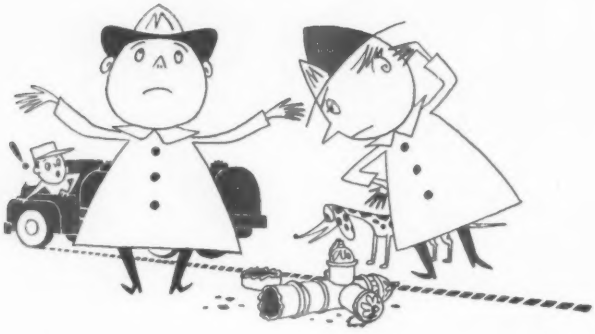

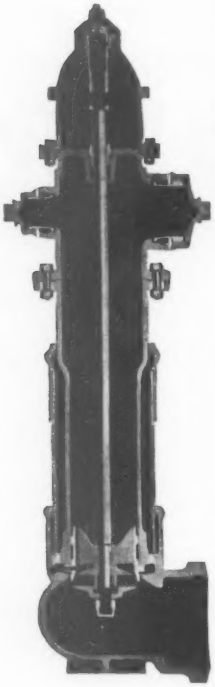

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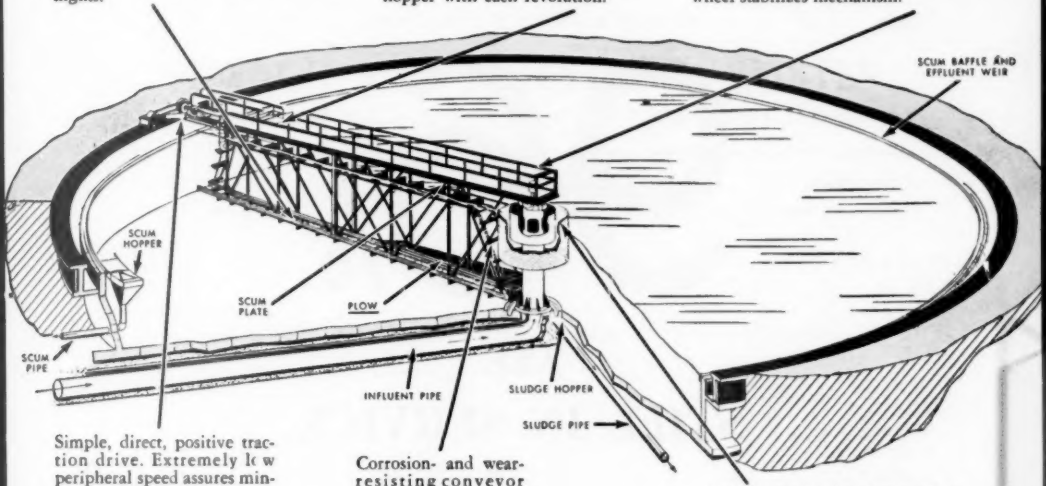

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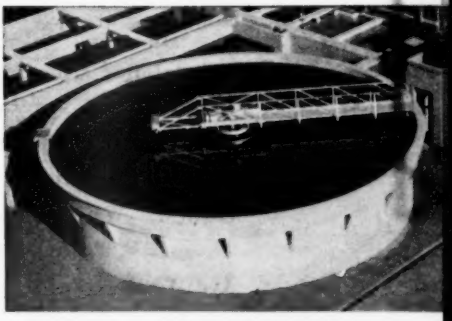

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 24 | **July, 1952** | **Number 7**

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Sewage Works

ELUTRIATION AS A SUBSTITUTE FOR SECONDARY DIGESTION *

By Wilbur N. Torpey and Martin Lang

Civil Engineer and Assistant Civil Engineer, New York City Department of Public Works, New York, N. Y.

The Jamaica sewage treatment plant is located on the north shore of Jamaica Bay in the Borough of Queens, New York City. This plant treats approximately 40 m.g.d. of sewage by the modified aeration, or high-rate activated sludge process. After passing through the coarse screens and grit chamber, the raw sewage is aerated in the presence of biologically active sludge for 2 hr. About 0.40 to 0.45 cu. ft. of air is supplied to each gallon of sewage treated. Aeration tank effluent is settled before discharge into Jamaica Bay.

Captured solids are removed to a separate sludge thickening tank for concentration. The thickened sludge, on a monthly basis, averages 6 to 7 per cent total solids, with a volatile content of 70 to 80 per cent. These concentrations of a biologically active sludge are obtained because of the low sludge age and the incorporation of the settleable solids fraction of the raw sewage.

The excess sludge is then pumped to separate digestion tanks, where it undergoes two-stage digestion. In 1950, more digesters were allotted to primary digestion to maintain adequate digester temperature, thus overcoming the effects of incrustation on the heating coils. The digester gas is utilized in gas engines to produce power. Only a small proportion of the total power requirements has to be purchased.

The digested sludge is pumped through a long pipeline to a storage tank on a navigable channel of Jamaica Bay. The sludge is then barged to sea by self-propelled sludge vessels, which also serve other New York City plants.

Vessel Schedule Critical

The removal of sludge from the Jamaica plant presents a more difficult problem than is encountered at the other plants. In traveling through Jamaica Bay the vessels traverse a narrow tortuous channel. Maintenance of a regular schedule is difficult because of the necessity of a favorable combination of weather and tidal conditions. An increased frequency of boat trips accentuates these difficulties. Furthermore, increased allocation of the vessels to the Jamaica plant disrupts operation schedules and curtails boat trips to other plants. Unfortunately, during the years 1947–50, an increase in the number of boat trips to Jamaica became necessary.

During this period, it was observed that the digested sludge carried to sea was slowly decreasing in concentration. The decrease is shown in Figure 1, which is a graphical representation of the variation of concentration of solids in the Jamaica digested sludge *versus* the volatile contents of that sludge. For purposes of comparison, similar data on digested sludge from

* Presented at a meeting of the Metropolitan Section, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Nov. 27, 1951.

the Coney Island, Bowery Bay, and Tallmans Island plants have been plotted. The points shown were derived from the grouped monthly averages. Within the limits of solids and volatile concentrations encountered, and with substantially uniform total digestion periods, the relationship is approximated by a series of parallel straight lines.

Digested primary solids attain the highest concentration, whereas digested sludge from a mixture of primary and activated solids assumes the lowest concentration. Digested sludge from plants using the modified aeration process falls in an intermediate position. It is evident that the differences in concentration of digested sludges, at a given volatile content, are highly influenced by the degree of biological treatment received prior to digestion.

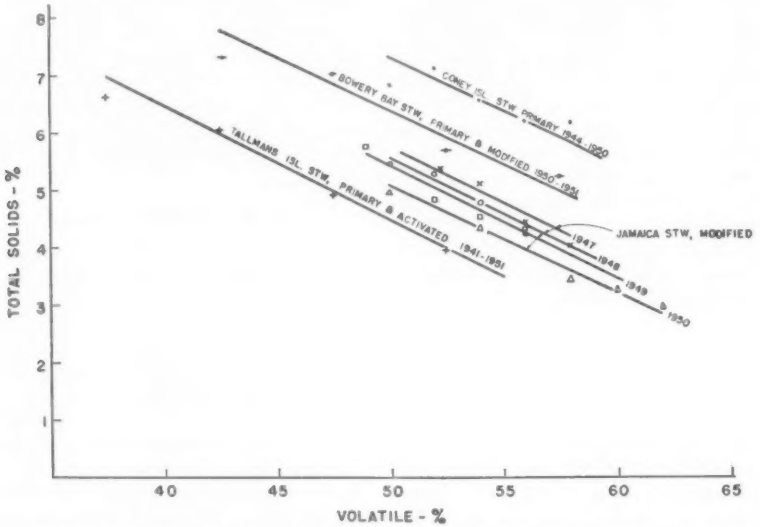

FIGURE 1.—Relation of concentration of digested sludge to per cent volatile.

During 1950, the digested sludge at Jamaica dropped to low concentrations. It was necessary to carry digested sludge to sea in quantities almost equal to the volume of excess sludge pumped, to avoid circulating large quantities of digested solids through the treatment process. A method of concentrating the digested sludge solids was urgently needed.

It was decided, therefore, to study and evaluate the application to Jamaica of elutriation for degassing and concentrating digested sludge solids. In this process digested sludge is intimately mixed with plant effluent and subsequently settled. The purpose was solely the concentration of sludge—as contrasted with the familiar objective of elutriation; namely, the reduction of coagulant dose in vacuum filtration. Further concentration of elutriated sludge by storage was also to be studied.

Conversion to Elutriation

The actual experimental work commenced in March, 1951, when one of the existing excess sludge thickening tanks was converted to an improvised elutriator (Figure 2). This tank is 55 ft. in diameter, with a sidewall depth of 10 ft. The tank has a center feed, peripheral effluent weirs, and a conical

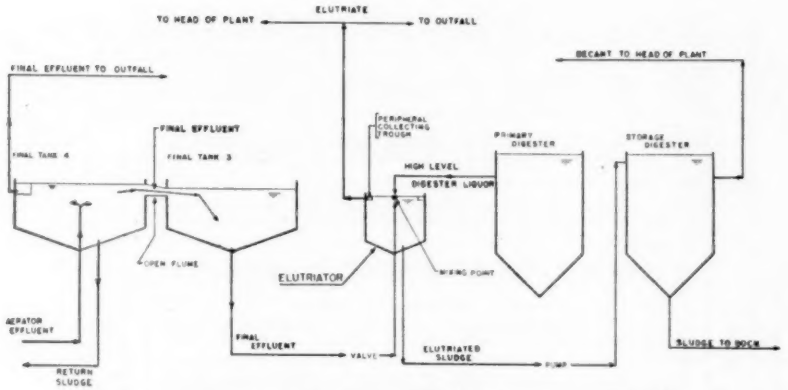

FIGURE 2.—Schematic profile showing thickener used as elutriation tank.

bottom. It is equipped with a "picket fence" collecting mechanism.

To introduce the final effluent into the elutriation tank it was necessary to build a flume from final tank No. 4 to final tank No. 3. Then final tank No. 3 was used to transfer varying quantities of final effluent from final tank No. 4 to the elutriator, the flow being controlled by a valve on the connecting line. The final effluent was introduced up the center feed line, where it met and was mixed with high-level digester liquor. The construction of the small wooden flume was the only actual structural change made in order to conduct the experiment. The elutriate (elutriator effluent) was discharged to the head of the plant.

This arrangement was operated for a total of 70 days. High-level digester liquor of 2 to 3 per cent total solids was fed to the elutriator in quantities ranging from 6,500 to 20,000 cu. ft. per day, and was mixed with from 4 to 13 volumes of final effluent. The resulting data, in the form of 3- to 5-day averages, are shown in Table I, which

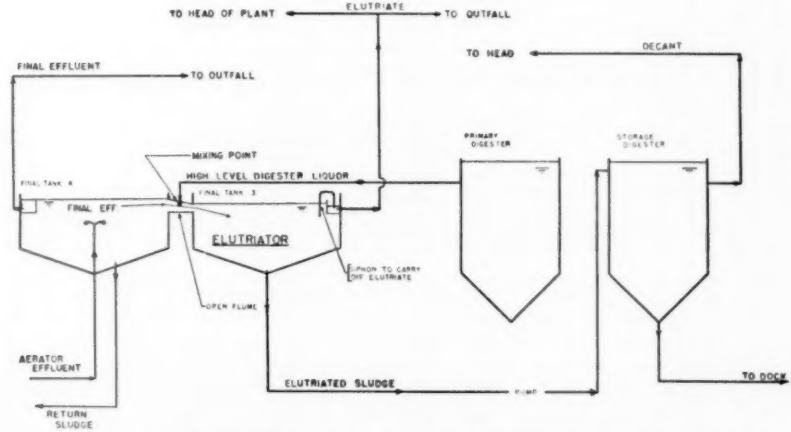

FIGURE 3.—Schematic profile showing final settling tank used as elutriation tank.

TABLE I.—Data for Elutriation Experiment (3- to 5-Day Averages) Using Thickener Tank [1,6]

Dates (1951)	No. of Days	Load per Day[2]				Diluting Final Effluent per Day				Elutriated Sludge per Day				Loading Rate (lb./sq. ft./day)[3]	Elutriate[4]			Liquid Detention (hr.)	Overflow Rate (gal./sq. ft./day)	Sludge Blanket Depth (ft.)	$\frac{C_e}{C_o}$ Overboard $\left(\frac{17}{6}\right)$
		(cu. ft. × 1,000)	Tot. Sol. (%)	Volatile (%)	Dry Sol. (tons)	(cu. ft. × 1,000)	Ratio $\left(\frac{7}{3}\right)$	Susp. Sol. (p.p.m.)	Dry Sol. (tons)	(cu. ft. × 1,000)	Tot. Sol. (%)	Volatile (%)	Dry Sol. (tons)		Susp. Sol. (p.p.m.)	Susp. Sol. (tons/day)	B.O.D. (p.p.m.)				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
3/25–27	3	13.5	2.37	53.6	10.0	121	9	19	.08	4.5	5.14	52.8	7.3	6.1	431	1.7	82	3.6	410	3[5]	17.0
3/28–30	3	10.2	2.11	53.0	6.7	84	8	31	.09	3.7	4.92	50.7	5.7	4.7	432	1.3	80	5.3	370	3[5]	19.4
3/31–4/2	3	15.1	2.49	52.1	11.6	107	7	32	.10	5.3	4.96	51.2	8.4	7.0	1,029	3.9	146	3.9	360	2[5]	33.7
4/3–5	3	16.9	2.51	44.6	13.3	107	6	16	.06	5.5	5.62	44.4	9.7	8.1	584	2.3	189	3.8	360	1[5]	17.3
4/6–8	3	19.1	2.85	46.6	17.0	120	6	17	.06	7.8	5.86	43.9	14.4	12.0	739	3.2	115	3.5	410	2[5]	18.8
4/9–12	4	19.5	2.44	49.9	11.0	120	9	20	.07	5.8	5.21	46.2	9.7	8.1	411	1.8	100	3.5	400	3[5]	16.3
4/13–16	4	13.3	2.27	48.8	9.5	110	9	27	.10	5.8	4.54	48.2	8.3	6.9	302	1.1	82	3.9	370	5[5]	11.6
7/5–9	5	6.5	2.46	55.8	4.9	78	13	26	.07	0.8	5.40	49.1	2.4	2.0	184	0.4	87	5.2	260	1.5	8.2
7/10–14	5	7.3	2.04	56.3	4.6	74	10	24	.06	2.2	5.24	51.8	3.6	3.0	206	0.5	78	5.7	250	2.0	10.9
7/15–19	5	7.4	2.25	59.8	5.3	74	11	19	.04	1.5	5.17	54.9	2.5	2.1	212	0.5	85	5.6	250	2.0	9.4
7/20–24	5	8.5	2.29	56.1	6.2	74	9	27	.06	2.5	5.18	54.0	4.2	3.5	420	1.0	93	5.5	250	4.0	16.1
7/25–27	3	7.9	2.65	52.5	6.3	74	10	25	.06	3.0	5.46	53.6	5.1	4.2	204	0.5	79	5.6	250	2.0	7.9
8/3–5	3	16.7	1.96	47.3	10.4	74	5	17	.04	4.5	6.53	42.4	9.2	7.7	820	2.2	157	5.2	270		21.2
8/6–8	3	18.5	2.27	54.7	12.9	74	4	18	.04	13.0	4.16	47.4	16.7	13.9	705	1.8	262	5.7	250		14.0
8/9–11	3	18.6	2.35	52.6	13.6	74	4	24	.06	12.3	3.96	50.6	15.1	12.6	516	1.2	229	5.6	250	Blanket Fluctuating	8.8
8/12–14	3	19.5	2.28	50.1	13.7	74	4	24	.05	10.7	3.94	49.3	13.2	11.0	461	1.2	207	5.5	260		8.8
8/15–17	3	17.8	2.51	49.3	14.1	74	4	26	.06	9.5	4.62	50.1	13.7	11.4	445	1.1	168	5.5	260		7.8
8/18–20	3	20.0	2.63	48.5	16.5	74	4	25	.06	9.8	4.49	48.6	13.0	10.8	661	1.8	196	5.4	260		10.9
8/21–23	3	15.5	2.40	50.7	12.2	74	5	21	.05	8.7	4.56	49.9	12.4	10.3	331	0.8	121	5.7	250		6.6
8/24–26	3	13.2	2.51	51.2	10.4	74	6	21	.05	7.5	4.61	48.2	11.0	9.1	197	0.5	73	5.7	250		4.8

[1] West thickener tank: capacity, 25,000 cu. ft.; cross-section, 2,100 sq. ft. at weir, 2,400 sq. ft. in sludge zone; sidewall depth, 10 ft.

[2] High-level digester liquid.

[3] Pounds of solids per square foot per day settling into the sludge zone; calculated by $\frac{\text{lb. dry solids pumped/day}}{\text{area of tank}}$.

[4] Elutriation tank effluent.

[5] Feet of clear liquor above diffuse sludge; blanket not well defined.

[6] Non-weighted arithmetic averages.

TABLE II.—Data for Elutriation Experiment (2- to 4-Day Averages) Using Final Tank No. 3[1,6]

Dates (1951)	No. of Days	Load per Day[2]				Diluting Final Effluent per Day				Elutriated Sludge per Day				Loading Rate (lb./sq. ft./day)[3]	Elutriate[4]			Liquid Detention (hr.)	Overflow Rate (gal./sq. ft./day)	Sludge Blanket Depth (ft.)	% Overboard ($\frac{17}{6}$)
		(cu. ft. × 1,000)	Tot. Sol. (%)	Volatile (%)	Dry Sol. (tons)	(cu. ft. × 1,000)	Ratio ($\frac{7}{3}$)	Susp. Sol. (p.p.m.)	Dry Sol. (tons)	(cu. ft. × 1,000)	Tot. Sol. (%)	Volatile (%)	Dry Sol. (tons)		Susp. Sol. (p.p.m.)	Susp. Sol. (tons/day)	B.O.D. (p.p.m.)				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
4/17–19	3	15.6	2.31	56.3	11.5	400	26	22	.27	0.0	—	—	—	1.4	248	3.3	77	8	275	0.0	28.7
4/20–22	3	15.5	2.05	52.3	10.0	400	26	26	.32	6.0	5.24	51.0	10.1	1.8	203	2.6	54	8	275	0.2	26.0
4/23–24	2	18.2	2.19	53.9	12.6	400	22	43	.54	—	—	—	—	1.6	280	3.6	61	7	275	1.2	28.6
4/25–26	2	17.5	2.48	49.9	13.8	400	23	23	.28	4.6	5.60	52.2	8.2	1.4	342	4.4	68	6	275	2.0	31.9
4/27–29	3	16.2	2.39	52.6	12.4	400	25	29	.36	5.3	6.05	50.7	10.3	1.8	353	4.6	75	6	275	—	37.1
4/30–5/2	3	18.2	2.77	51.7	15.9	155	9	28	.14	4.8	6.48	48.8	10.1	1.8	369	1.8	80	15	110	2.0	11.3
5/3–5	3	18.3	2.73	51.1	15.7	133	7	30	.12	4.8	6.17	48.5	9.6	1.7	391	1.8	138	17	100	2.0	11.5
5/6–8	3	19.6	2.63	49.7	16.1	133	7	33	.14	4.8	6.38	46.8	9.8	1.7	473	2.1	145	17	100	2.0	13.0
5/9–11	3	17.2	2.44	53.4	13.1	133	8	29	.12	4.9	6.43	47.9	10.1	1.8	510	2.3	190	17	100	2.5	17.5
5/12–14	3	20.5	2.69	51.2	17.3	133	7	21	.09	5.7	6.53	49.0	11.8	2.1	584	2.6	98	17	100	3.0	15.0
5/15–17	3	18.0	2.74	51.8	15.5	133	7	33	.13	4.7	6.38	48.8	9.6	1.7	538	2.5	112	16	100	3.0	16.1
5/18–20	3	15.5	2.62	51.0	13.0	133	9	28	.12	3.8	6.70	48.4	8.2	1.4	469	2.1	156	16	100	3.0	16.1
5/21–23	3	13.3	2.56	52.4	10.7	133	10	40	.16	4.0	6.98	49.2	8.9	1.6	450	2.0	143	16	100	3.0	18.7
5/24–27	4	15.8	2.87	49.8	14.2	133	9	30	.12	4.0	7.07	47.2	9.0	1.6	569	2.6	156	16	130	3.0	18.3
5/28–31	4	20.3	2.96	47.6	18.9	240	12	30	.23	4.6	7.01	47.2	10.3	1.8	624	5.0	148	9	160	3.0	26.5
6/1–4	4	18.3	2.89	50.2	16.5	240	14	29	.22	5.1	7.28	46.7	11.9	2.1	625	5.0	139	9	160	3.7[5]	30.3
6/5–6	2	21.2	2.63	48.5	17.8	240	12	24	.18	6.0	7.40	44.7	14.3	2.5	614	4.9	167	9	160	2.0	27.6
6/7–9	3	8.9	2.86	48.7	8.1	240	29	29	.22	3.6	7.32	45.7	8.6	1.5	219	1.8	71	10	160	2.0	22.3
6/10–12	3	11.7	2.66	51.1	9.8	240	21	31	.23	3.2	7.12	46.7	7.4	1.3	219	1.7	55	10	160	1.5	17.3
6/13–15	3	15.3	2.32	48.3	11.2	240	16	37	.28	2.2	7.33	47.1	5.1	0.9	273	2.2	85	11	160	1.5	19.6
6/16–18	3	13.6	2.67	53.7	11.4	240	19	33	.25	2.7	7.35	47.8	6.4	1.1	413	3.3	78	10	160	2.0	29.0
6/19–21	3	12.4	2.61	51.7	10.3	240	20	30	.23	2.4	7.41	48.3	5.7	1.0	296	2.4	87	10	160	2.0	23.3
6/22–23	2	13.4	2.84	50.8	12.0	240	18	43	.32	1.8	7.24	47.9	4.2	0.7	420	3.3	105	10	160	2.5	27.5

[1] Final tank No. 3: capacity, 140,700 cu. ft.; cross-section, 10,000 sq. ft. at weir, 11,300 sq. ft. in sludge zone; sidewall depth, 10 ft.

[2] High-level digester liquid.

[3] Pounds of solids per square foot per day settling into sludge zone; calculated by $\frac{\text{lb. dry solids pumped/day}}{\text{area of tank}}$.

[4] Elutriation tank effluent.

[5] Blanket dropped by transfer of 22,000 cu. ft. of sludge to thickener.

[6] Non-weighted arithmetic averages.

indicates that approximately 13 per cent of the solids fed to the elutriator were lost in the elutriate. The settled solids ranged in concentration from 3.9 to 6.5 per cent total solids, depending on the volatile content and the volume of sludge fed to the elutriator. The volume of the elutriated sludge averaged from 25 to 50 per cent of the volume of the high-level digester liquor fed to the elutriator.

An alternate arrangement, using final tank No. 3 as an elutriator, is shown in Figure 3. Final tank No. 3 is a circular settling tank, 120 ft. in diameter, with center feed and peripheral weirs. It is equipped with a rotary collecting mechanism. Sidewall water depth is 10 ft.

Elutriation Studies

Final effluent entered final tank No. 3 from final tank No. 4 through the previously mentioned flume. High-level digester liquor was introduced and intimately mixed with final effluent in this flume. The elutriate was removed from final tank No. 3 by siphons. The results showed that siphons were a poor method of removing elutriate. However, the primary consideration in this instance was not elutriate quality, within limits, but sludge concentration.

This arrangement was operated for a total of 68 days. Although the volume of high-level digester liquor fed daily was similar to that fed the thickener (Figure 2), it was introduced into a tank having approximately 5 times the area. Digester liquor was diluted with from 7 to 29 volumes of final effluent. The resulting data, in the form of 2- to 4-day averages, are shown in Table II.

As previously mentioned, the elutriate was not of good quality, as it contained approximately 22 per cent of the solids fed to the elutriator. The settled sludge concentrated to from 5.2 to 7.4 per cent total solids, and its volume averaged 30 per cent of the volume fed to the elutriator.

To analyze the performance of the elutriators it is necessary to utilize some loading criteria. It was evident from the data that elutriate quality was affected by the overflow rate, expressed as gallons per square foot per day.

In correlating the data pertaining to sludge concentration, the variables exerting the greatest influence were the rate at which elutriated solids passed through the tank and the tank areas involved. These variables were combined in the form of a "loading rate," expressed as pounds of dry solids removed per square foot per day. Such a criterion was used in preference to pounds of dry solids added per square foot per day to eliminate the effect of varying quantities of solids lost in the elutriate.

The thickening tank was operated at loading rates ranging from 2 to 14 lb. per sq. ft. per day, and the final tank at rates ranging from 1 to 3 lb. per sq. ft. per day. A total range of loading rates of from 1 to 14 lb. per sq. ft. per day was thus explored.

The concentrations of solids and volatile of the elutriated sludge were then grouped according to loading rates, and averaged. These averages were superimposed on that portion of Figure 1 relating to the Jamaica plant and are shown in Figure 4 as the circled points. The numbers adjacent to these circled points represent the corresponding loading rates.

Within the limits of the concentrations of solids and volatile presented, the slope of the solids-volatile relationship of Jamaica sludge has already been established in Figure 1. Analysis of selected data, before averaging, for the elutriated sludge results in essentially the same slope for the solids-volatile lines.

Lines with the same slope as the lines representing the solids-volatile relationship for digested sludge were

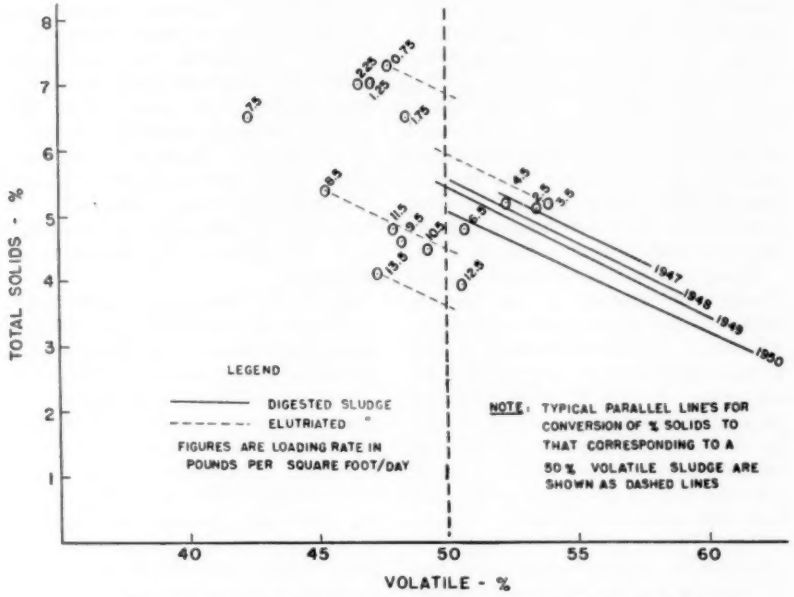
TOTAL SOLIDS - %
VOLATILE - %
LEGEND
DIGESTED SLUDGE
ELUTRIATED
FIGURES ARE LOADING RATE IN POUNDS PER SQUARE FOOT/DAY
NOTE: TYPICAL PARALLEL LINES FOR CONVERSION OF % SOLIDS TO THAT CORRESPONDING TO A 50% VOLATILE SLUDGE ARE SHOWN AS DASHED LINES
1947
1948
1949
1950

FIGURE 4.—Relation of concentration of digested and elutriated sludges to per cent volatile.

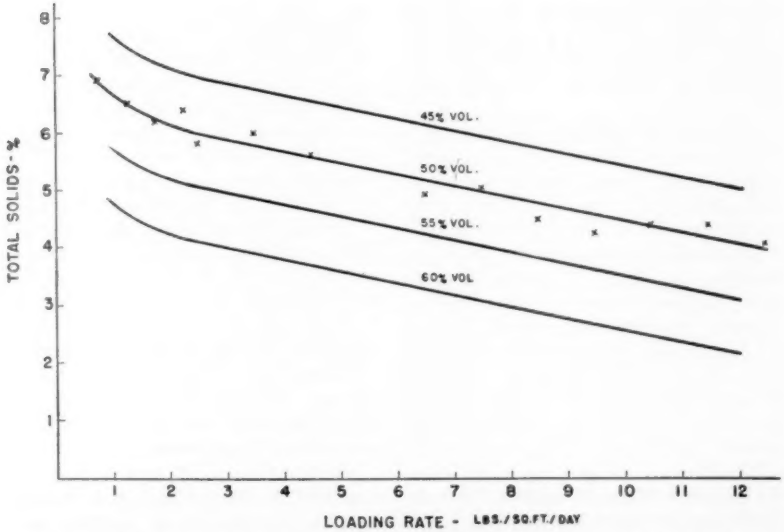

FIGURE 5.—Relation of loading rate to concentration for various per cent volatile sludges.

passed through the individual points for each loading rate. These lines indicate the solids-volatile relationship for elutriated sludge at each loading rate. The effect of varying loading rates on the concentration of elutriated sludge, for any given volatile content, may now be determined. For the purpose of illustration, several of these construction lines were drawn and are shown as dashed lines in Figure 4.

Thus, for a 50 per cent volatile sludge, the intercept of any loading rate with the 50 per cent vertical line was read. These concentrations were plotted against their respective loading rates. A smooth curve was then passed through these points. In a similar manner, the loading versus concentration curves for 45, 55, and 60 per cent volatile sludges were derived. These are shown in Figure 5.

Using Figure 5, the efficiency of the elutriator in concentrating sludge can be compared to the Jamaica secondary digestion tanks. These comparisons were made on the basis of a 50 per cent volatile sludge. From Figure 4, the solids concentrations for a 50 per cent volatile digested sludge were obtained. These concentrations were related to an equivalent elutriator loading.

For example, in 1947 the concentration of Jamaica digested sludge, corresponding to 50 per cent volatile, was 5.75 per cent. On the 50 per cent volatile curve of Figure 5, this concentration corresponds to an elutriator loading rate of 3.7 lb. per sq. ft. per day. The loading rate of the secondary digesters for that year was 0.7 lb. per sq. ft. per day, calculated on the same basis as the elutriation tanks. In 1948, the secondary digester loading was 0.7 lb. per sq. ft. per day, and the comparable elutriator loading would be 4.7 lb. per sq. ft. per day. In 1949, the respective figures were 0.8 lb. per sq. ft. per day and 5.1 lb. per sq. ft. per day. This comparison could not be drawn for 1950 because considerable quantities of digested sludge were drawn from the primary digesters.

Thus, considering the results for 1947, an elutriator with about one-fifth (0.7/3.7) the area would have yielded the same concentration as did the secondary digesters. For each of the years 1948 and 1949, the same concentrations could have been obtained in an elutriator of about one-sixth the area of the secondary digesters.

If, on the other hand, consideration is given to the volume of the elutriator *versus* the volume of the secondary digesters, it is necessary to introduce the equivalent cylindrical depths of the tanks, which are approximately 11 ft. for the elutriators and 22 ft. for the digesters. Elutriation, then, would have accomplished the equivalent of the 1947–1949 Jamaica secondary digester performance in concentrating digested solids, with but from one-tenth to one-twelfth the volume.

It should be pointed out that the major contribution of secondary digestion is the concentration of sludge solids, with consequent reduction of sludge volume. Gas production from the secondary digesters amounts to but 10 per cent of the total gas generated. Substitution of elutriation for secondary digestion would, therefore, result in the loss of 10 per cent or less of the available gas, depending on the method of operation of the primary digesters.

The quality of the elutriate was such that the elutriate carried away from 5 to 30 per cent of the solids applied. The thickener functioned much better in this respect than the final tank. However, the thickener was operating in accordance with the intent of its design, whereas the final tank was handicapped by the improvised flume and siphon arrangement.

The data showed that increasing the depth of the sludge blanket or increasing the overflow rate resulted in a greater percentage of the applied solids being carried away in the elutriate.

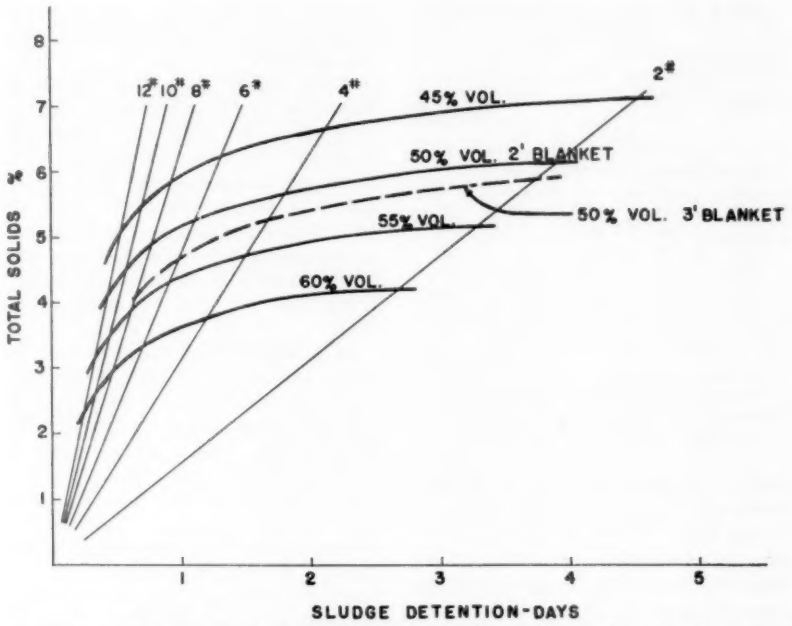

FIGURE 6.—Relation of elutriated sludge concentration to sludge detention for various loading rates.

However, the indications were that the solids spillover, in the case of the thickener, could be held to less than 15 per cent of the applied load by holding the sludge blanket below 3 ft. and the overflow rate below 400 g.p.d. per sq. ft.

Although liquid detention in the elutriator varied from 4 to 17 hr., solids were stored in the blanket for periods ranging up to several days. The concentration attained by the sludge solids will depend, to a large extent, upon the length of time they are held in the sludge blanket. This is shown in Figure 6.

In deriving Figure 6, it was assumed that the equivalent of a 2-ft. blanket was maintained, based on the concentration of sludge being removed. Then, from Figure 5, at any given loading rate and volatile condition, the weight of dry solids stored in the blanket per unit area can be calculated from the corresponding solids concentration. This weight of solids held per square foot, divided by the weight of solids removed per square foot per day (loading rate), equals the sludge detention time in days.

In order to show what possible error might be involved in the assumption of the equivalent of a 2-ft. blanket rather than a 3-ft. blanket, the curve of total solids *versus* time is plotted for both depths for a 50 per cent volatile sludge. The resulting difference is about 0.3 to 0.5 per cent total solids. This difference does not invalidate the basic direction of the derived curves.

Figure 6 is confined between sludge detention times of 0 and 5 days so that the critical first 3 days of compaction are shown in detail. The curves show that the greatest increase in sludge concentration took place

TABLE III.—Changes in Elutriated Sludge during Storage

Dates (1951)	Elapsed Time (days)	Sludge Conc.[1]		Per Cent Decantable by Volume[2]
		Sol. (%)	Vol. (%)	
3/11–4/7	Filling	(5.0)[3]	(50.9)[3]	—
4/5	25	7.7	49.0	0
4/24	44	7.8	48.5	33
5/1	50	8.6	—	54
5/8	58	9.5	—	58
5/16	66	9.9	46.7	54
5/24	74	9.4	46.8	58
5/31	81	10.8	44.1	63
6/7	88	10.5	45.6	67

[1] At base of sidewall.
[2] Volume of clear liquor (less than 0.4 per cent solids) referred to total digester volume.
[3] Averages of elutriated sludge added.

within the first day, with a progressively slower rate of compaction up to 2 or 3 days. Beyond 2 or 3 days, further gains in solids concentration are limited. As a guide to the interpretation of Figure 6, the lines showing the loading rates in the elutriator are drawn. From Figure 6 it is apparent that if any marked increase in concentration above that attained in the elutriator is desired, an extended period of storage will be necessary. To investigate this phenomenon, elutriated sludge was pumped into an empty, unheated digestion tank. The filling period took 28 days and the sludge was thereafter held under quiescent conditions for an additional 60 days. The results for holding elutriated sludge during this period are shown in Table III.

Because the sampling device could not reach the bottom of the hopper, the sludge concentrations shown are those at the base of the sidewall. Some random samples of sludge pumped from the bottom of the digester reached concentrations of more than 12 per cent solids. The "per cent decantable" in Table III indicates the volume of clear liquor (less than 0.4 per cent total solids) referred to the total volume of the digester. The per cent decantable by volume increased with storage time.

These results show that storage of elutriated sludge will produce marked decreases in the volume of sludge to be removed. The exact holding period is uncertain because of the 28 days required to fill the digester. Thus, the time required to produce a given volume of decantable liquor may very well be less than that shown in Table III, if the time were not lost in filling the tank.

It should be noted that although the sludge increased in concentration from 5 per cent total solids to more than 10 per cent, there was a concomitant decrease in the volatile content from 51 to about 45 per cent. This represents more than 20 per cent destruction of the volatile matter. Temperature measurements were not taken in the digester, as volatile destruction of this magnitude was not expected at a temperature of about 60° F.

With the attainment of sludge concentrations of well over 10 per cent, it appeared that the Jamaica problem was solved. However, the resulting sludge could not be pumped through almost 2 mi. of pipeline to the sludge storage tank. When the sludge approached concentrations in the order of 9 per cent solids, it became extremely viscous, due to the formation of a stable hydrogel. Attempting to pump this gelatinous sludge to sludge storage resulted in excessive pressure in the line. A considerable portion of this sludge was readily pumped, however, to emergency sludge beds on the plant grounds. It was noted that the sludge dried to the extent of surface cracking in about 3 days.

An attractive feature of prolonging storage of elutriated sludge until it reaches the highly concentrated gelled condition, is that reduction in volume to about 20 per cent of the original excess sludge volume can be obtained.

A practical solution, with the pres-

ent facilities, may be to so control storage of elutriated sludge as to obtain maximum concentration within the limits of pumping. Under these conditions, and maintaining concentrations approaching 8 per cent, only from 25 to 30 per cent of the raw sludge volume would have to be carried to sea.

Summary

At the Jamaica sewage treatment plant, low concentrations of digested sludge required an increased number of boat trips, with consequent difficulties in sludge vessel operation as applied to sludge removal from other plants.

The use of elutriation and elutriation plus storage for concentrating Jamaica digested sludge was studied and evaluated.

High-level digester liquor, averaging 2 to 3 per cent total solids, was concentrated in a single-stage elutriator. The elutriated sludge contained from 3.9 to 7.4 per cent total solids, depending on volatile content and loading rate.

An analysis of the thickening phenomena involved in concentrating elutriated sludge was made, based on the fundamentals of time, area, and loading, expressed as a loading rate.

Satisfactory increases in sludge concentration were obtained without excessive loss of solids in the elutriate, by proper control of elutriator operation.

A single-stage elutriation tank was found to be as effective in concentrating digested sludge solids as a secondary digester with 12 times the volume.

By quiescent storage of elutriated sludge with 5 per cent total solids, a gradual increase in concentration occurred. A sludge with more than 10 per cent total solids was obtained after 80-day storage.

In the course of this study, digester operation was simplified by the use of the elutriator. No adverse effect on the modified aeration process was noted as a result of sending elutriate back to the wet well. It was apparent that full-scale application of elutriation to the Jamaica plant would materially reduce the volume of sludge to be barged to sea.

Acknowledgments

Thanks are extended the operating and laboratory staff of the Jamaica sewage treatment plant, and the other members of the Bureau of Sewage Disposal Operation for their cooperation in carrying out these studies.

DISCUSSION

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The foregoing report by Messrs. Torpey and Lang certainly shows outstanding ability to set up controlled experimental procedure with the view of correlating the collected data in order to find a successful solution of a pressing engineering problem. In so doing they have shown by means of more thorough-going field research than usual and the novel graphic organization of their data that the proper combination of sludge digestion and elutriation expands the value of both for sludge disposal in general.

Using elutriation between the biologically active and less active storage stages of digestion, as described in the report, has been termed "intermediate elutriation" by Fraschina (1) in his report on operations at the Richmond-Sunset Plant, San Francisco, Calif. In Germany, where its use was

was recently initiated, it has been termed the "Genter-Kennedy" process (2)(3).

The theory is relatively simple. Years of practice have shown that elutriation is an excellent means of concentrating digested sludge and clarifying digester supernatant liquor (1). In diluting digested sludges and dirty sludge liquor with water, relatively free of dissolved gases, the buoyant gases imbibed in the digested and digesting solids pass into solution. The solids are actually degassed, gain in specific gravity, and settle rapidly to a denser sludge than issues from the digester, leaving the supernatant water relatively clean.

The purposes of intermediate elutriation are numerous and related to the chief disclosures emphasized by Messrs. Torpey and Lang, as follows:

1. It increases the efficiency of active, primary digestion space through accelerating and facilitating the production of relatively clear elutriate and digester supernatant in both the elutriation and secondary storage space. Returning these overflowing top waters to the fresh sludge collecting system eliminates the effects of the vicious cycle of recirculating digested solids between the fresh and digested sludge tanks. This cycle both bulks the collected fresh sludge and robs the active digestion space of needed capacity.
2. It materially reduces the B.O.D. of the digester supernatant and solves the bothersome problem of its disposal.
3. It decreases required secondary digestion space.
4. It simplifies digester operation.
5. It offers a simple and efficient means of eliminating volatile acids and their cause of digester foaming.
6. It materially shrinks the volume of final sludge destined for disposal.
7. It saves sludge bed and lagooning space and drying time where vacuum filters are not used, and, as noted by the authors, puts more pounds of sludge solids in a cubic foot of transportation space.

In referring to Figure 1, the authors state: "It is evident that the differences in concentration of digested sludges, at a given volatile content, are highly influenced by the degree of biological treatment received prior to digestion." This is primarily due to the capacity of the large sludge floccules produced in sludge activation for enmeshing and retaining large amounts of water. Usually digestion alters this voluminous floc structure very little. A digested sludge consisting of highly dispersed fines also produces a thin sludge.

Although the loading rates of 1 to 14 lb. digested solids per square foot daily were explored by the authors, one should remember that the digested sludge produced at the Jamaica plant is strictly digested waste activated sludge. It contains no digested primary sedimentation sludge and, therefore, represents one of the most difficult sludges to thicken, even by intermediate elutriation. Notwithstanding this fact, the single elutriation tank showed revolutionary results in solids concentration. The loading rate is a function of the sludge volatile, floc structure, and amount of initial dewatering desired in the intermediate elutration step. At the Richmond-Sunset plant the high initial fresh sludge volatile (82.5 per cent) is reduced to 61.5 per cent in primary digestion (0.95 cu. ft. of space per capita) leaving 46 per cent of the original solids. Solids leaving primary digestion for intermediate elutriation run about 2.65 per cent, which is a quite similar concentration to that reported by the authors, as well as a similar loading rate. This concentration is raised to 5.2 per cent, principally in secondary digestion storage (0.45 cu. ft. of space per capita), with the production of a clear supernatant. During 1949–50 the average removal of suspended solids in this

primary treatment plant was 71 per cent, with an average B.O.D. removal of 48 per cent.

With digested sludges of 50 per cent or less volatile contents, loading rates of 40 lb. solids per sq. ft. of tank area are obtainable. Instances can be cited where the sludge was too heavy to remove from the elutriation tank (20 per cent solids) after standing 12 hr. and from secondary storage without the help of sludge collectors and special pumping equipment.

The total loss in suspended solids is a function of sludge blanket thickness, overflow rate, and dilution rate used. At the highest loading rates of Table I (for example 8/6–8 to 8/24–26) the elutriation ratios and losses were relatively low. These losses had no adverse effect on the modified aeration system. The losses are evidently of minor importance because they are chemically inert. The B.O.D. of the elutriate overflowing both the intermediate elutriation and secondary storage tanks was noticeably low at Jamaica and certainly is at Richmond-Sunset and Baden-Baden. At Richmond-Sunset it looks as though the loss is more than canceled out by the positive gains. The amount of diluted supernatant as elutriate returned to the plant influent at an elutriation ratio of 4 or 5 to 1 is a small fraction of the plant flow and adds far less to the average B.O.D. load than does returning digester supernatant of 1,000 p.p.m. or more suspended solids. The B.O.D. of the digester supernatant and intermediate elutriate is largely a direct function of the concentration of suspended solids.

As to the loss of 10 per cent or less of the available gas production through the use of intermediate elutriation, this can be fully reduced in more ways than one. At Baden-Baden the floating cover for gas collection is placed over the secondary storage digester and all gas conducted to that holder. According to the disclosures of Table III, if prolonged storage is so effective in further volatile destruction, the gas evolved in this storage can be readily collected. It also is possible to recover any loss by reheating the final highly contracted volume of washed sludge. This has been done by simply transporting some of the final stored sludge back to active digestion.

As a result of Richmond-Sunset practice, the new and larger Southeast or main treatment plant at San Francisco is now using intermediate elutriation on a more complete scale than at Richmond-Sunset. On the basis of the experience gained at Richmond-Sunset, Poepel (2) designed the intermediate elutriation layout for Baden-Baden, Germany. This plant has been operating for more than a year. The elutriate overflowing the small secondary storage digester has a lower B.O.D. than the plant influent and the final sludge sent to the sand beds contains about 15 per cent solids and dries rapidly, according to reports. Intermediate elutriation is to be used in the new treatment plants at Tacoma, Wash., and Sacramento, Calif., and is provided for at Ann Arbor, Mich., and at the Hyperion plant in Los Angeles, Calif. It will be used also in various manners prior to lagooning the final sludge at the new Wilmington, Del., plant (4). Although Cleveland, Ohio, will clarify the high-level secondary digester overflow by elutriation in its improved Southerly plant, the elutriated solids will go directly to vacuum filtration along with the other elutriated digested solids.

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TESTS TO DETERMINE OXYGEN ABSORPTION RATING OF POROUS PLATE AIR DIFFUSERS

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The Sanitary District of Chicago has long felt the need for a method of rating air diffusers that would definitely assure the purchaser a product of uniform performance regardless of the source of supply. With this object in view, considerable work and study have been devoted to the problem during the last year. As a consequence, an oxygen absorption rating test has been developed to supplement present specifications, which should prove a valuable aid to both the manufacturer and purchaser of porous air diffusers.

Permeability Rating

The porous plate air diffusers used in activated sludge plants most generally are made of either silicon dioxide or aluminum oxide grains cemented into a porous mass by a ceramic binder, pressed, dried, and burned. They are graded according to their capacity to pass air when dry, a characteristic called "permeability," which is defined as the number of cubic feet of free air, at 70° F., passing through 1 sq. ft. of plate at a pressure loss of 2 in. of water. Diffuser plates have been specified and purchased on the basis of permeability rating ever since they have been used for diffusing air in the activated sludge process. Nevertheless, the same permeability does not mean that plates made by different manufacturers are essentially equivalent in grain and pore sizes. This is self-evident, as a plate with a small number of large pores could have the same rating as another with a large number of small pores. The two plates, however, would have entirely different characteristics in regard to air diffusion and clogging.

Oxygen Absorption Most Important Factor

The flow of air through a dry plate certainly is not a good criterion for evaluating its suitability for diffusing air into water, unless related to some other more direct and informative test. The actual amount of oxygen absorbed by the mixed liquor in an aeration tank is the determining factor in any comparison of diffuser plates. The volume of air required to produce a certain amount of absorption should be the basis for comparing diffuser plate efficiency. Therefore, it was decided to set up a test for measuring the oxygen absorption in water aerated by diffused air from a porous plate. The best method of doing this appeared to be by the aeration of water containing sodium sulfite in solution, one of the methods used by the U. S. Public Health Service (1) for measuring atmospheric reaeration in stream flow.

Oxygen Absorption Measurements in Sulfite Solution

In the USPHS measurements two comparative tests were made using (a) sulfite solution and (b) deaerated water. Except at very low velocities the results were approximately the same by both means. Diffused air aeration produces considerable turbulence. Therefore, it was quite probable there would be little difference in the oxygen absorption occurring in the aeration of either deaerated water or sulfite solution. The latter is the more

practical method and for that reason has been used in the tests reported herein.

In water containing sodium sulfite, the dissolved oxygen remains at zero, as the oxygen going into solution immediately unites with the sulfite to form sulfate, the reaction being:

$$Na_2SO_3 + O \text{ (from the water)} = Na_2SO_4$$

By measuring the decrease in sulfite concentration in relation to time, the rate of oxygen absorption can be readily determined. This can be done by collecting, at intervals, a sample of fixed amount from the solution; adding to this a predetermined amount of acidified iodine solution. The iodine unites with the sulfite, the reaction being:

$$Na_2SO_3 + I_2 + H_2O = Na_2SO_4 + 2HI.$$

By adding each sample to such a fixed amount of iodine solution that there is always iodine in excess of the amount required to neutralize the sulfite solution, the change in sulfite concentration can be determined by measuring the change in the excess iodine for each interval. This is done by titrating the excess of iodine with N/40 sodium thiosulfate. For a 50-c.c. sample of the sulfite solution a titration of 1.0 c.c. of the sodium thiosulfate is equivalent to 4.0 p.p.m. of oxygen absorption. By titrating the sodium thiosulfate into a measured quantity of the iodine solution used for the tests, a relation can be established for computing the sulfite concentration in each sample of sulfite solution.

Experimental Tank

Preliminary tests indicated that in order to get consistent results a definite pattern of overturning currents should obtain in the sulfite solution in the experimental tank. It was decided, therefore, to use the circulating type of tank. A steel tank, available at the North Side plant, was ideally suited for the purpose. Figure 1 shows the baffles and fillets that were specially installed to make the tank approximately a one-fifth scale model of the cross-section of the aeration

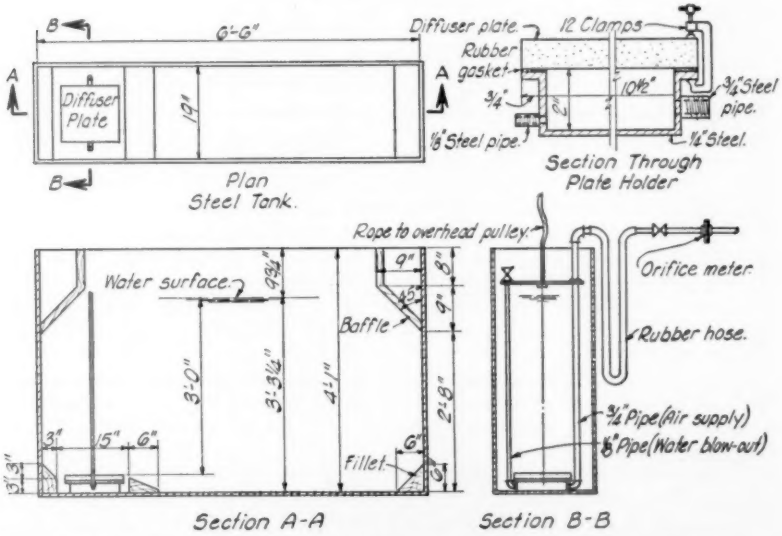

FIGURE 1.—Oxygen absorption rating tank for porous plate air diffusers.

tanks at the West-Southwest plant, which are 32 ft. 9 in. wide with 15 ft. water depth on the diffuser plates. The experimental tank is 6 ft. 6 in. by 19 in. in plan and was operated with 3-ft. water depth on the diffuser plate. The plate area ratio was 1 to 10, the same as for four rows of plates in the West-Southwest tanks.

A steel plate holder was used as shown in Figure 1. The plate was clamped on top of the holder against a rubber gasket seat by means of 12 wood clamps. An air supply pipe and a water blow-out pipe were connected to the holder on opposite sides. These two pipes, at a point just above the water surface, were attached to a bar, from which a rope extended to an overhead pulley. A section of hose was connected into the air supply piping to provide flexibility and permit the raising and lowering of the plate holder without disconnecting the air. It was thus possible to install a plate on the holder and lower it just below the water surface for inspection with the air on before lowering it to the bottom of the tank for testing. The test setup proved to be very satisfactory in all respects.

Test Procedure

In general, the test procedure was about as follows. First, the tank was filled to 3 ft. above the top elevation of the diffuser plate with water tempered to 72° F., the temperature maintained in all the tests. The plate to be tested was clamped to the holder, lowered just below the water surface, and inspected with air diffusing. It was then lowered to the bottom of the tank and the air rate set and maintained at 1.0 cu. ft. per min. [60° F. and 14.4 lb. per sq. in. (abs.)]. Then 2.5 lb. (about 1,200 p.p.m.) of sodium sulfite were gradually added by dissolving in water taken from the tank and pouring the solution back in. The

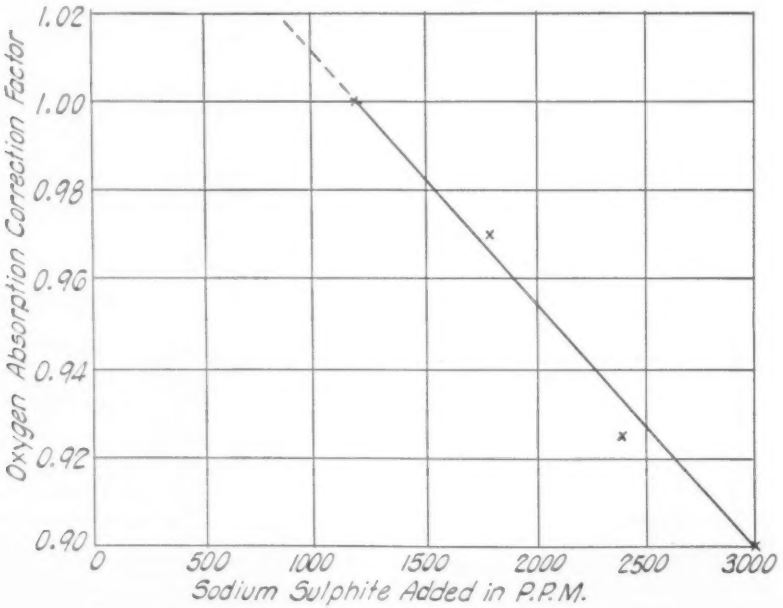

FIGURE 2.—Correction factors for oxygen absorption rating test.

pH was brought to about 7.0 by adding 100 c.c. of N/40 sulfuric acid. The plate was then tested for a period of 30 to 60 min. by sampling at 10- or 15-min. intervals. The test was then repeated with another plate, and so on until the sulfite concentration became too low for further tests. The samples were taken with a 50-c.c. pipette from the solution just below the surface at the end of the tank away from the diffused air.

Several factors affecting the results had to be considered. The rate of oxygen absorption increased slightly when more sodium sulfite was added. The tests were standardized on an addition of 1,200 p.p.m., but at times it was convenient to add more sulfite instead of emptying and refilling the tank. To take care of such tests the results were corrected in accordance with Figure 2.

Another important factor to be considered, not realized in the first tests, was the effect of moisture in the pores of the plates. By soaking a plate for several hours to a day or more, the rate of oxygen absorption could be increased over that when tested dry. The improvement was about 10 per cent for new plates and more for used plates, sometimes as much as 30 to 40 per cent. After soaking, plates gave consistent results on repeat runs. On the other hand, it was almost impossible to keep a plate thoroughly dry internally in an initial test and to test it again in exactly the same condition. If the air were off for only an instant some moisture went down into the plate. If only a portion of the plate were dry most of the air diffused through that part. To get better distribution of the air throughout the entire plate the procedure adopted in the first tests was to submerge each diffuser for a few minutes before the air was turned on. This was improved on by wetting a plate under the faucet for a while before testing. Such procedures apparently resulted in various degrees of internal wetting. Later, when it was realized that a thorough wetting of diffusers was desirable for consistency in results and to more closely approximate actual operating conditions, the plates from then on were soaked in water, preferably for a day or more, before being tested. The results thus obtained should be used as the basis for comparing diffuser plates.

Most of the plates were tested with the edges sealed with cement to confine all air diffusion to the top surface, such as occurs in installations in aeration tanks. Used plates had to be sealed in such a manner, otherwise considerable air would issue from the edges, a condition that did not obtain in actual operation. With new plates, however, the air discharging from the edges was minor and apparently had no measurable effect on the results. Therefore, the sealing of the edges of new plates was discontinued after December, 1951.

Test Data

The results of the tests on oxygen absorption for new and used plates diffusing air at the rate of 1.0 cu. ft. per min. (32 cu. ft. per min. per 1,000 cu. ft.) into sodium sulfite at 72° F. in the circulating type of experimental tank, are shown in Table I. The results are summarized in Table II for plates thoroughly soaked before being tested. The oxygen absorptions obtained with new (clean unused) plates as summarized in Table II (*a*) are plotted in relation to permeability in Figure 3. It is to be noted that the relationship is close to a straight line except for the N 40 plates (4 tested at average permeability of 43.1) and the E 80 plates (10 tested at average permeability of 80.7). In each of these two cases the grain size, by visual inspection, appeared larger than in the plates of corresponding permeability following the general trend. The N 40 plates had a coarser grain than the N 33 or C 40; and the E 80 plates had larger grains than the N 80 or C 80,

TABLE I.—Air Diffuser Tests in Na_2SO_3 Solution in Circulating-Type Tank [1, 2]

Plate				Na_2SO_3 Conc. (p.p.m.)		Test		Corrected O_2 Absorp.	
Date	Description	Prep.[3]	Air Distr.	Added	Test Av.	Time (min.)	Oxygen Absorp. (p.p.m./hr.)	Factor	(p.p.m./hr.)
			(*a*) F Plates						
10/26/51	New 24, No. 1	D	Good	1,550	650	60	60.8	0.98	59.3
11/ 2/51	New 24, No. 1	S 1/12	Good	1,200	790	90	63.4	1.00	63.4
12/ 7/51	New 24, No. 1	S 3	Good	1,200	1,050	30	61.7	1.00	61.7
11/27/51	Used 16, No. 1	S 1/12[4]	Good	1,200	960	45	53.4	1.00	53.4
11/29/51	Used 16, No. 1	S 1/12[4]	Good	1,200	1,020	30	53.4	1.00	53.4
11/27/51	Used 16, No. 2	S 3*	Good	1,200	450	45	52.3	1.00	52.3
			(*b*) E Plates						
12/ 6/51	New 75, No. 1	S 1/12	Good	1,200	410	45	32.3	1.00	32.3
12/ 6/51	New 75, No. 1	S 1/12	Good	1,800	820	30	33.0	0.966	31.9
12/10/51	New 75, No. 1	S 4	Good	1,800	410	45	36.2	0.966	34.9
12/10/51	New 75, No. 1	S 4	Good	3,000	930	45	39.2	0.90	35.2
12/12/51	New 75, No. 1	S 6	Good	1,200	1,100	45	35.3	1.00	35.3
12/10/51	New 75, No. 2	S 4	Good	3,000	420	45	37.9	0.90	34.2
12/12/51	New 75, No. 2	S 6	Good	1,200	420	45	37.4	1.00	37.4
11/16/51	New 76, No. 1	S 1	Fair	1,200	440	45	35.8	1.00	35.8
11/23/51	New 76, No. 1	S 1/24	Fair	2,400	700	60	39.4	0.933	36.7
12/12/51	New 76, No. 1	S 20	Fair	1,200	860	45	35.8	1.00	35.8
10/22/51	New 81, No. 1	D	Fair	1,200	870	75	37.5	1.00	37.5
10/26/51	New 81, No. 1	D	Fair	1,200	680	60	35.2	1.00	35.2
12/19/51	New 81, No. 1	S 2	Fair	1,200	970	60	38.5	1.00	38.5
1/ 3/52	New 81, No. 2	S 1	Fair	1,200	670	45	38.4	1.00	38.4
1/ 3/52	New 81, No. 3	S 1	Fair	1,200	390	45	36.2	1.00	36.2
1/25/52	New 81.5, No. 1	S 7	Fair	1,200	1,060	30	34.4	1.00	34.4
10/30/51	New 82, No. 1	D	Poor	850	680	45	36.2	1.02	36.9
10/23/51	New 83, No. 1	D	Poor	1,200	420	60	33.4	1.00	33.4
10/30/51	New 83, No. 1	S 1/24	Poor	850	400	60	32.8	1.02	33.5
11/15/51	New 83, No. 1	S 1	Poor	1,200	1,030	45	33.8	1.00	33.8
1/14/52	New 85, No. 1	S 11	Fair	1,200	680	30	33.5	1.00	33.5
1/25/52	New 85, No. 2	S 2	Fair	1,200	650	30	36.2	1.00	36.2
11/20/51	Used 76, No. 1	S 1/12[4]	Good	1,200	940	60	39.8	1.00	39.8
11/21/51	Used 76, No. 1	S 1/12[4]	Good	1,200	440	60	39.7	1.00	39.7
11/20/51	Used 76, No. 2	S 1/12[4]	Good	1,500	400	60	39.7	0.983	39.1
			(*c*) N Plates						
11/ 5/51	New 33, No. 1	W	Good	1,200	560	60	55.2	1.00	55.2
12/17/51	New 33, No. 1	S 3	Good	1,200	760	45	54.7	1.00	54.7
1/14/52	New 33, No. 2	S 11	Good	1,200	960	30	58.3	1.00	58.3
10/25/51	New 43.1, No. 1	D	Fair	1,200	740	60	42.5	1.00	42.5
12/14/51	New 43.1, No. 1	S 2	Good	1,200	540	45	46.6	1.00	46.6
10/25/51	New 43.1, No. 2	D	Good	1,200	360	45	47.8	1.00	47.8
1/ 3/52	New 43.1, No. 2	S 1	Good	1,200	340	45	49.8	1.00	49.8
1/24/52	New 43.1, No. 3	S 1	Good	1,500	890	30	53.4	0.983	52.4
1/24/52	New 43.1, No. 4	S 1	Good	1,500	630	45	52.0	0.983	51.3
10/23/51	New 76.5, No. 1	D	Good	1,800	540	45	42.5	0.966	41.2
12/19/51	New 76.5, No. 1	S 2	Good	1,500	490	45	46.2	0.983	45.4
10/26/51	New 81.5, No. 1	D	Fair	1,200	1,020	45	40.2	1.00	40.2
12/ 6/51	New 81.5, No. 1	S 10	Good	1,200	870	75	43.8	1.00	43.8
1/23/52	New 84, No. 1	S 5	Good	1,500	400	30	46.2	0.983	45.4

TABLE I.—Air Diffuser Tests in Na_2SO_3 Solution in Circulating-Type Tank—Continued

Plate				Na_2SO_3 Conc. (p.p.m.)		Test		Corrected O_2 Absorp.	
Date	Description	Prep.[3]	Air Distr.	Added	Test Av.	Time (min.)	Oxygen Absorp. (p.p.m./hr.)	Factor	(p.p.m./hr.)
			(c) N Plates—*Continued*						
1/23/52	New 84, No. 2	S 5	Good	1,500	650	30	44.3	0.983	43.6
1/23/52	New 117, No. 1	S 5	Fair	1,200	570	30	36.1	1.00	36.1
1/24/52	New 117, No. 2	S 1	Fair	1,500	410	20	34.7	0.983	34.2
11/ 5/51	New 124, No. 1	W	Fair	1,200	1,020	60	32.1	1.00	32.1
12/19/51	New 124, No. 1	S 2	Fair	1,200	470	60	33.8	1.00	33.8
11/ 9/51	Used 40±, No. 1	W	Poor	1,200	970	60	42.1	1.00	42.1
11/13/51	Used 40±, No. 1	S 4	Fair	900	330	30	43.9	1.027	45.1
11/23/51	Used 40±, No. 1	S 14	Fair	2,400	360	30	48.0	0.934	44.9
10/29/51	Used 40±, No. 2	D	Fair	1,800	370	45	44.8	0.966	43.3
11/14/51	Used 40±, No. 2	S 5	Good	1,200	870	60	50.7	1.00	50.7
11/ 6/51	Used 40±, No. 3	W	Fair	600	340	60	36.4	1.032	37.7
11/14/51	Used 40±, No. 3	S 5	Good	1,350	770	60	51.3	0.991	50.9
11/13/51	Used 80±, No. 1	S 4	Good	600	340	45	50.2	1.035	51.9
12/ 5/51	Used 80±, No. 1	S 20	Good	2,100	900	45	52.9	0.95	50.4
12/ 5/51	Used 80±, No. 2	S 2	Good	2,100	450	45	51.7	0.95	49.2
12/17/51	Used 80±, No. 3	S 3	Good	1,500	450	30	53.4	0.983	52.5
			(d) C Plates						
1/24/52	New 37.3, No. 1	S 1	Good	1,200	930	40	61.9	1.00	61.9
1/24/52	New 37.3, No. 2	S 1	Good	1,200	590	30	58.3	1.00	58.3
10/17/51	New 41, No. 1	D	Poor	960	730	60	40.7	1.01	41.1
10/23/51	New 41, No. 1	W	Good	2,000	340	30	52.9	0.955	50.5
12/14/51	New 41, No. 1	S 2	Good	1,200	940	55	55.2	1.00	55.2
1/ 3/52	New 41, No. 2	S 1	Good	1,500	340	45	56.9	0.983	56.1
1/14/52	New 41.7	S 11	Good	1,200	440	30	56.1	1.00	56.1
1/23/52	New 83, No. 1	S 5	Good	1,200	1,020	30	47.9	1.00	47.9
1/23/52	New 83, No. 2	S 5	Poor	1,200	770	30	40.7	1.00	40.7
10/29/51	New 84.5, No. 1	D	Good	1,200	950	45	42.1	1.00	42.1
12/17/51	New 84.5, No. 1	S 3	Good	1,200	470	45	40.7	1.00	40.7
10/29/51	New 84.5, No. 2	D	Poor	1,800	680	45	36.7	0.966	35.6
11/ 5/51	New 84.5, No. 2	W	Fair	1,500	430	75	41.2	0.983	40.6
1/25/52	Reburned 40±, No. 1	S 1/4	Good	1,200	440	30	54.8	1.00	54.8
1/ 2/52	Used 40±, No. 1	S 15	Good	1,200	530	45	46.8	1.00	46.8
12/10/51	Used 40±, No. 2	S 4	Good	3,000	1,300	45	55.3	0.90	49.8
1/ 2/52	Used 40±, No. 3	S 15	Good	1,500	490	45	47.3	0.983	46.5
1/ 2/52	Used 40±, No. 4	S 15	Good	1,200	1,020	45	48.8	1.00	48.8
11/ 9/51	Used 41.1, No. 1	S 1/12	Good	1,200	510	60	50.0	1.00	50.0
11/14/51	Used 41.1, No. 1	S 5	Good	1,350	360	30	51.1	0.991	50.6
11/ 9/51	Used 41.1, No. 2	S 1/12	Good	1,350	340	15	48.8	0.991	48.4
11/15/51	Used 41.1, No. 2	S 1	Good	1,200	740	45	49.3	1.00	49.3

[1] Tank 6 ft. 6 in. by 1 ft. 7 in.; water depth on plate, 3.0 ft.

[2] Air rate, 1.0 c.f.m. at 60° F. and 14.4 lb. per sq. in. (abs.); solution temperature, 72° F.

[3] D = put in dry and submerged for several minutes before turning on air; W = wet under faucet for about ½ hr. before testing; S = soaked in water prior to test for number days indicated; and New = clean unused plates.

[4] Removed from aeration tank Nov. 20, 1951.

TABLE II.—Oxygen Absorption for Plates Thoroughly Soaked Before Testing

Plate		Number Tested	Perm.[1]	Oxygen Absorp. (p.p.m./hr.)[1]
Type	Nom. Perm.			
(*a*) New (Clean Unused) Plates				
C	40	5	39.9	57.6
C	80	3	83.5	43.6
E	80	10	80.4	36.0
F	24	1	24.0	62.5
N	33	2	33.0	56.5
N	40	4	43.1	50.0
N	80	4	80.7	44.6
N	120	3	119.3	34.1
(*b*) Used Plates				
C	40	6	40±	49.3
E	80	2	76.0	39.3
F	16	2	16±	52.9
N	40	3	40±	49.0
N	80	3	40±	50.6

[1] Average.

which appeared very similar to each other in structure. The N 40 plates produced about 90 per cent as much oxygen absorption as the C 40 plates; the E 80 plates about 80 per cent as much as the N and C plates of 80 permeability.

The oxygen absorption rates for used plates were quite different from those that obtained when new. This was to be expected, as plates in service soon become dirty and coated. It is of interest, however, to note that in the Sanitary District, after a period of service, plates of low permeability lose in efficiency, whereas those of higher permeability improve. There were no unused original F 16 plates available for testing, but from Figure 3 it seems probable that such plates would have tested about 63 p.p.m. per hour of oxygen absorption in the experimental tank. Using this value, the efficiencies of used plates in relation to new were about as shown in Table III.

TABLE III.—Comparison of Used with New Plate Efficiencies

Plate		Oxygen Absorp. (p.p.m./hr.)		Used, in Per Cent of New	Service Life of Used Plates (yr.)
Type	Nom. Perm.	New	Used		
F	16	63	52.9	84	22
C	40	57.0[1]	49.3	86	2 to 10
N	40	51[1]	49.0	96	6 to 10
N	80	44.5[1]	50.6	113	4
E	80	36[1]	39.3	109	1

[1] Interpolated from Figure 3.

Application of Data

The oxygen absorption ratings obtained in the tests apply only for the conditions and tank of the size used in the tests. Nevertheless, they do serve as a reflection of the relative efficiencies of the plates for air diffusion. To convert the results to plant-size tanks requires more experimental data. Studies in this regard are in progress in the Sanitary District.

The lower the oxygen absorption rating of a new plate the larger its pores and the longer its service (2) before pressure losses become excessive due to clogging from dust particles in the air. The best plate for use in any particular plant is that which will result in the lowest over-all cost for air for sewage treatment. Installation of plates of quite low rating in oxygen absorption may result in excessively high air consumption for a period of years, more than offsetting the savings due to longer service, low pressure losses, and low costs for air filtering. Installation of plates of quite high oxygen absorption rating may result in short service and high pressure losses more than offsetting the advantages of the initially high efficiency in air diffusion. On the other hand, future developments may show economy in the use of plates of quite high oxygen absorption rating if it can be demonstrated that the initial efficiency can be retained and long service assured at low pressure losses

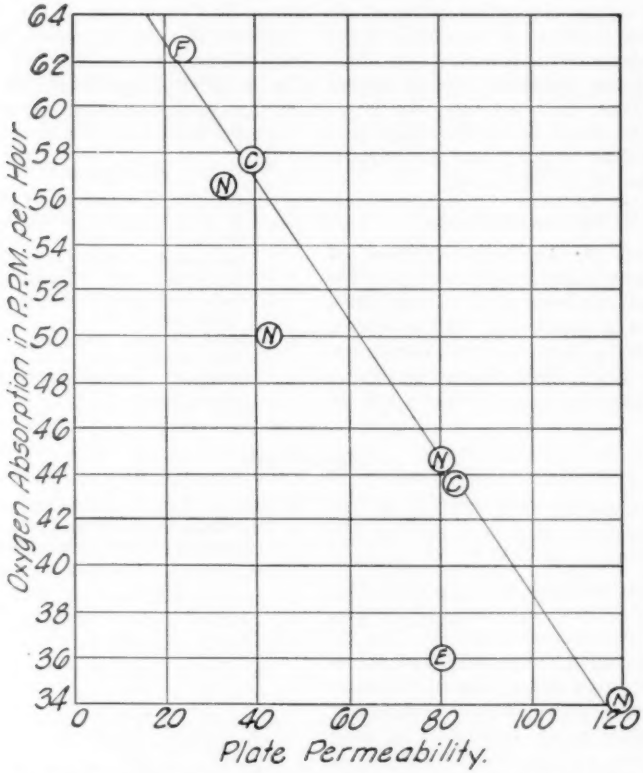

FIGURE 3.—Oxygen absorption ratings of clean unused diffuser plates.

by providing air filtration of an exceptionally high degree of efficiency. These are only a few of the problems involved in the selection of the air diffusers for any plant, which can be met with greater intelligence when more data become available on the oxygen absorption ratings of new and used plates as related to the peculiarities of various sewage treatment plants.

Conclusions

Purchase of porous plate air diffusers on the basis of permeability results in wide variations in the air diffusing and clogging characteristics of products from different sources, and also from one source, due to changes in manufacturing technique. Under such circumstances no manufacturer should be criticized if his product does not perform as well as a competitor's made to the same specifications. The fault is an inadequate specification.

The oxygen absorption rating of porous plate air diffusers would assure the purchaser of obtaining a product of uniform performance, regardless of the source of supply. This test should be specified in the purchase of plates and applied to enough of them picked at random to be sure they produce the oxygen absorption required. The present permeability rating should be retained to assure uniformity.

The oxygen absorption rating of air diffusers would be a protection to the purchaser and the manufacturer alike. The former would be sure of getting the diffuser he wants and the latter would be secure in the knowledge that his product is suited for the purpose for which it is to be used.

Acknowledgments

Norval E. Anderson, engineer of treatment plant design, is responsible for the work being done on which this article has been based. The tests were initiated by the writer and were made at the North Side sewage treatment plant with the cooperation and help of John R. Palmer and E. H. Morgan, engineer of plant operation and principal chemist, respectively. W. A. Dundas is general superintendent and W. H. Trinkaus is chief engineer of The Sanitary District of Chicago.

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APPENDIX

In connection with the oxygen absorption rating of porous plate air diffusers, another method of grading plates, investigated in the Sanitary District, is of interest because of the simplicity of the test involved. The air passing through dry plates at various pressure losses was measured. The ratio of the rates of flow at two selected pressure losses is an indication of pore sizes when applied to several different plates. For example, in the permeability rating test the flow of air through the plates is viscous for low permeabilities and a combination of viscous and turbulent for high permeabilities. The larger the pores in a plate, the more turbulent the flow and, as a consequence, the larger the ratio of the rate of flow at any particular pressure loss to that obtaining at twice that loss. Table IV gives the ratios of the rates of air flow through dry, clean unused plates at pressure losses of 0.5 and 1.0 in. of water.

TABLE IV.—Ratio of Air Flow Rates Through Dry, Clean Unused Plates at Pressure Losses of 0.5 and 1.0 In. of Water

Plate		Flow Ratio (%)
Type	Perm.	
N	33.0	51.1
C	41.0	52.2
N	43.1, No. 1	57.4
N	43.1, No. 2	57.0
N	76.5	57.8
N	83.1	58.2
N	84.0	59.0
E	81.0, No. 1	62.7
E	81.0, No. 2	62.2
N	124.0, No. 1	62.5
N	124.0, No. 2	63.2

If the results given in Table IV are plotted on Figure 3 using an inverted scale for the flow ratio, a remarkable resemblance to the oxygen absorption rating is apparent. Therefore, if more fully developed this test might be used instead of oxygen absorption measurements to supplement the permeability rating in the purchase of new plates. The flow ratio test, however, is of no value on used plates and does not possess the direct and informative nature of the oxygen absorption rating.

RAPID FILTRATION OF SEWAGE EFFLUENTS THROUGH SAND AND ANTHRACITE*

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Conditions in inland areas of Great Britain are such that sewage from towns of any size must be treated to give an effluent of high quality, but there are some places, usually where the volume of dilution water in the receiving stream is small, where it is becoming desirable or even necessary to produce an effluent of specially high quality, which is not readily attainable by the conventional methods of treatment. There is also an increasing tendency to look to sewage effluents as a possible source of cooling water, and for this purpose too an effluent of very high quality is desired, particularly with respect to the content of suspended solids.

At one time slow sand filters, somewhat similar to those used for treatment of water, were extensively used in Great Britain for giving a final polish to sewage treatment plant effluents. However, the process is cumbersome, as suspended matter arrested by the filter has to be removed by manual scraping, and beds of considerable area (of the order of 1 acre per m.g.d. of effluent treated) have to be used. For these reasons the process has been abandoned at all but a few relatively small works. As rapid sand filters have now been in use for many years for treatment of water, it seemed a logical step to use this kind of filter, which does not suffer from the disadvantages of the slow sand filter, for removal of suspended solids from sewage effluent. Experiments with this object in view were undertaken by the Water Pollution Research Laboratory at Luton, England, where an average dry-weather flow of 7.2 m.g.d. (U. S.) of effluent is discharged to the bed of the River Lee, which is practically dry immediately above the point of discharge. Apart from the fact that the River Lee passes in its course through ornamental lakes, it is used in its lower reaches as a source of about one-sixth of the water supply of London. It is therefore of the utmost importance that the river should be kept in good condition.

Preliminary Experiments with Closed Pressure Filters

Preliminary experiments, first in the laboratory, and then with a pair of closed cylindrical pressure filters each 2 ft. in diameter, established the fact that from 72 to 92 per cent of the suspended solids in humus tank effluent from the percolating filter plant at Luton could be removed by filtration through sand at rates of 120 to 240 g.p.h. (U. S.) per square foot (1). Very useful accompanying reductions in biochemical oxygen demand and in amount of oxygen absorbed from permanganate were also brought about. A bed of sand 2 ft. deep was adequate, and it was important that the grading of the sand should not depart greatly from − 10 + 18 British Standard Sieve sizes; that is, the most suitable medium was a very coarse sand of nominal particle size 1.7 to 0.85 mm.

Solid matter arrested by the filter was removed by backwashing once

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daily with about 3 per cent of the volume of liquid filtered during the day, but it was found that to keep these closed filters in good condition without the use of an air scour (which was not provided), it was necessary to clean the sand with sodium hypochlorite solution about once a month.

The opportunity was also taken to try graded anthracite as a filtering medium. This behaved in much the same way as the sand, but it was rather easily lost during backwashing, and there was some evidence of degradation of particle size after prolonged use.

Open Rapid Gravity Filters

Once the feasibility of the process had been demonstrated, further experiments were made in open rapid gravity filters (2), which would be the type most likely to be used in a full-scale installation. Two pilot filters of this kind, each 14.06 sq. ft. in area, were constructed by Luton Corporation to the design of the Corporation's consulting engineers. A view of the pilot plant is given in Figure 1 and a flow diagram in Figure 2. Sectional steel plates, each 4 ft. square, were used to construct the filters (which had a total height of 12 ft.) and a storage tank (capacity 1,300 U. S. gal.) for filtered effluent. All pipe connections for liquid were 3 in. in diameter and there were two interchangeable centrifugal pumps for feeding the filters and for backwashing. The arrangement for drawing off filtrate from the bottom of the filter was of a proprietary design used in waterworks practice; it consisted of a number of small nozzles, protected by brass domes and connected to a main header channel, and lateral pipes embedded in concrete. Two superimposed 4-in. layers of gravel graded, respectively, ½ to ¼ in. and ¼ in. to 10 mesh, covered the floors and supported a 24-in. depth of medium in each filter. Filter G1 originally contained sand hand-graded to − 10 + 18 mesh and Filter G2 contained a machine-graded anthracite of

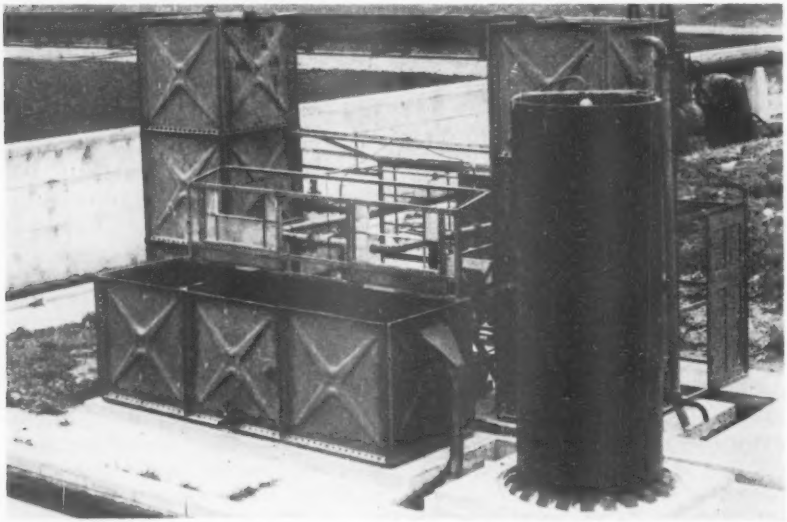

FIGURE 1.—Pilot open rapid gravity filters, Luton, England, sewage treatment plant. The circular tank in the foreground is a nitrifying filter, not part of the plant.

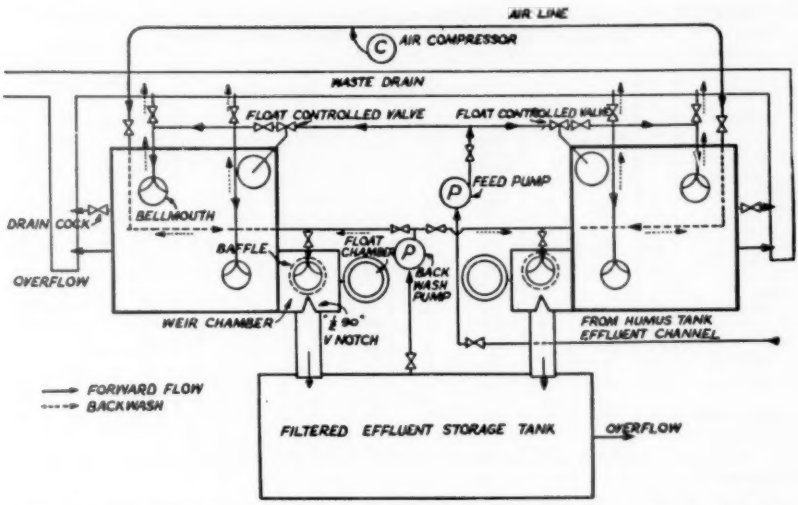

FIGURE 2.—Flow diagram of pilot open rapid gravity filters, Luton, England, sewage treatment plant.

nominal size 1 to 2 mm.; sieve analyses of samples of the media are given in Table I.

Liquid was admitted to each filter through two submerged bellmouth inlets, each 9 in. in diameter, and projecting about 5 in. above the surface of the medium; these also served as outlets when the filter was being backwashed. Filtered effluent was conveyed from the collecting channels in the floor of each filter through a bellmouth protected by a baffle, into a weir chamber, from which it flowed over a "half-90°" V-notch into the storage tank. From each measuring chamber a pipe led to a float chamber, above which was mounted a flow recorder. The rate of flow through the filters could be maintained at a desired value by a float-operated throttle valve in the inlet pipe to each filter. The maximum

TABLE I.—Results of Sieve Analyses (Per Cent by Weight Retained) of Media Used in Open Rapid Gravity Filters Treating Humus Tank Effluent from Luton, England, Sewage Treatment Plant

British Standard Sieve Size	Nominal Size of Particles (mm.)	Sept. 28, 1949 to May 1, 1950		May 4 to July 26, 1950	Aug. 16 to Sept. 12, 1950
		Filter G1[1]	Filter G2[2]	Filters G1 and G2[3]	Filter G2[4]
$\frac{3}{16}$ in. to No. 7	4.8 to 2.4	0	0.5	0	—
No. 7 to No. 10	2.4 to 1.7	80.4	36.9	15.5	12.0
No. 10 to No. 14	1.7 to 1.2			79.8	66.6
No. 14 to No. 18	1.2 to 0.85	18.8	60.6	4.0	21.1
No. 18 to No. 25	0.85 to 0.6			0.3	0.15
Passing No. 25	<0.6	0.8	2.0	0.4	0.15

[1] Sand, graded −10 + 18 mesh.
[2] Anthracite, graded 1 to 2 mm.
[3] Sand, hand-graded −8 + 18 mesh.
[4] Sand, commercially graded −8 + 18 mesh.

TABLE II.—Average Results of Mechanical Filtration of Effluent from Luton, England, Sewage Treatment Plants in Open Rapid Gravity Filters [1]

Period	Filter No.	Application Rate (g.p.h./sq. ft.)[2]	Head Loss[3] (ft.)	Suspended Solids			Oxygen Absorbed[4]			Biochem. Oxygen Demand[5]		
				Filter Infl. (p.p.m.)	Filter Effl. (p.p.m.)	Red. (%)	Filter Infl. (p.p.m.)	Filter Effl. (p.p.m.)	Red. (%)	Filter Infl. (p.p.m.)	Filter Effl. (p.p.m.)	Red. (%)
1949:												
Oct.	G1	89	6.0	34	4	88	16	9	44	29	14	52
	G2	71	6.1	34	1	97	16	9	44	29	7	76
Nov.	G1	82	3.9	30	3	90	17	12	29	23	7	70
	G2	90	4.4	30	2	93	17	11	35	23	5	78
Dec. 1-12	G1	112	5.4	21	1	95	15	11	27	29	3	90
	G2	109	5.1	21	0.5	98	15	11	27	29	3	90
1950:												
Jan.	G1	139	5.8	24	3	88	18	13	28	23	9	61
	G2	135	5.8	24	3	88	18	13	28	23	9	61
Feb.	G1	156	6.6	26	4	85	20	15	25	32	14	56
	G2	157	6.8	26	5	81	20	16	20	32	15	53
Mar. 1-21	G1	191	4.7	25	7	72	21	16	24	29	14	52
	G2	183	5.6	25	11	56	21	18	14	29	16	45
Mar. 22-31	G1	216	5.0	14	1	93	15	12	20	18	8	56
	G2	219	5.2	14	0.5	96	15	12	20	18	9	50
Apr. 1-May 1	G1	239	6.6	19	4	79	18	15	17	24	11	54

[1] Filter G1 contained sand, graded −10 + 18 mesh; filter G2, anthracite of 1- to 2-mm. nominal size.

[2] U. S. gallons.

[3] At end of 1 day's run, measured in feet of water.

[4] From acid N/80 $KMnO_4$ in 4 hr. at 26.7° C.

[5] In 5 days at 18.3° C.

loss of head was limited to 7 ft. by a second float operating on the same valve.

Loss of head was measured directly by the height of liquid in the filter above the free outlet. Approximate measurements were made originally by observation of mercury manometers, but float-operated recorders were later installed to record the loss of head directly on the weekly charts of the flow recorders.

A small compressor supplying 18.8 cu. ft. of free air per minute was used for scouring the filters before backwashing. Air was conveyed to the filters by 1-in. diameter pipes and was distributed through the water collecting nozzles in the floors.

From October to December, 1949, attempts were made to pump humus tank effluent to the filters at rates approximately proportional to the rate of flow of effluent from the works as a whole, but with the arrangements provided it was found impossible to do this and to maintain the desired average rate of filtration of at least 120 g.p.h. (U. S.) per square foot. In later experiments, therefore, humus tank effluent was pumped to the filters at rates which were kept approximately constant during each 24 hr. Once in each 24 hr. the filters were stopped for about 30 min. for backwashing; in this operation the filters were allowed to drain, and, after scouring with air, were backwashed with 2 to 3 per cent of the volume of water filtered during the previous run. A backwash rate of 800 g.p.h. (U. S.) per square foot was used for filter G1, and 500 to 600 g.p.h. (U. S.) per square foot for filter G2. The lower rate used for the filter containing anthracite was necessary to avoid losing large quantities of medium; some medium was lost because of difficulty in regulating the expansion of the bed.

Until the end of November, 1949, spot samples of humus tank effluent, before and after treatment in the filters, were collected; but in all later experiments composite samples were taken by automatic samplers, which operated during the period of peak

flow. Results of examination of the samples are given in Table II; each value for loss of head is the gross loss of head minus the loss of head in a clean filter at the final rate of filtration. Effluents of high quality were obtained from each filter up to the end of February, 1950, but in early March a marked deterioration was observed, particularly in effluent from the filter containing anthracite. On examination, the filter walls were found to be in a very clean condition and there was no large accumulation of organic matter in the filtering medium, but individual particles of sand and anthracite were covered with a gelatinous film, which was also found in the weir chambers. Discharge of this film apparently contributed to the inferior quality of the effluents. No great increase in loss of head was observed.

In an attempt to remove the organic matter from the medium, the filters were chlorinated on March 21 by adding to the wash-water tank sufficient sodium hypochlorite to give 0.05 per cent available chlorine, pumping this solution into the filters, and allowing to stand for 1 hr.; the filters were then scoured with air for about 1 hr. and backwashed in the normal way. A large quantity of apparently unorganized organic matter was discharged. It was considered that the accumulation was largely due to inadequate air scouring and in all experiments after this time each filter was scoured with air for 10 or 15 min. before each backwash instead of, as at first, for only 3 min. No further chlorination appeared necessary and the effluents produced were of excellent quality.

Table III gives the percentage of samples from each filter falling within given ranges of B.O.D. and indicates that there was little or no difference between the effluents from the two filters. The average weight of biochemical oxygen demand removed by filtration through sand was 0.43 lb. and by filtration through anthracite 0.42 lb., per sq. ft. per day.

TABLE III.—B.O.D. of Effluent from Humus Tanks at Luton, England, Before and After Mechanical Filtration (Oct. 1, 1949–Mar. 31, 1950)

B.O.D.[1] (p.p.m.)	Percentage of Samples		
	Filter Infl.	Effl. after Filt. through	
		Sand	Anthracite
0 to 10	2	44	44
10 to 20	16	47	44
20 to 30	49	9	12
30 to 40	21	0	0
40 to 50	7	0	0
>50	5	0	0

[1] In 5 days at 18.3° C.

During the period October, 1949, to March, 1950, five samples of humus tank effluent were found to contain more than 50 p.p.m. suspended solids. Little deterioration in the quality of the effluents from the two filters was observed on these occasions, and the average reduction in suspended solids was 96 per cent.

Effect of Depth of Filtering Medium

On May 1, 1950, the two filters were emptied and were refilled with 2 ft. and 3 ft. 6 in., respectively, of sand hand-graded to $-8+18$ mesh. Results of sieve analysis show that the sand was of slightly narrower grading and of larger average particle size than that originally used in filter G1 (Table I).

The free outlet from the filter containing 3 ft. 6 in. of medium was 16 in. lower than the surface of the sand and to ensure that the sand was flooded at the beginning of the run, the outlet valve was throttled and was gradually opened as the loss of head in the filter progressively increased during the first few hours of the run. There was no appreciable difference in the final loss of head in the two filters, measured by the height of the liquid above the free outlet.

TABLE IV.—Average Results of Mechanical Filtration of Humus Tank Effluent Through Pilot Open Rapid Gravity Filters (May 4–July 26, 1950)[1]

Sampling Point	Susp. Solids				Oxygen Absorbed[2]				B.O.D.[3]			
	Max.	Min.	Av.	Av. Red.	Max.	Min.	Av.	Av. Red.	Max.	Min.	Av.	Av. Red.
(*a*) Flow Rate; 140 to 205 G.P.H. per Sq. Ft.												
Filter infl.	41	10	19.3	—	23.5	10.5	16.8	—	40.0	9.5	23.8	—
Filter G1 effl.	3.0	0	0.9	95	14.0	9.0	11.8	30	14.5	4.5	7.2	70
Filter G2 effl.	1.5	0	0.7	96	14.5	8.5	11.5	32	11.0	5.0	6.3	74
(*b*) Flow Rate; 205 to 275 G.P.H. per Sq. Ft.												
Filter infl.	52	6	16.5	—	23.0	7.5	15.3	—	26.0	8.5	15.5	—
Filter G1 effl.	5.0	0	0.8	95	17.0	5.5	11.8	23	11.0	3.0	6.1	61
Filter G2 effl.	4.0	0	0.8	95	16.0	5.0	11.4	25	11.5	2.0	6.4	59
(*c*) Flow Rate; >275 G.P.H. per Sq. Ft.												
Filter infl.	27	6	14.5	—	16.5	10.5	13.1	—	24.5	9.0	14.8	—
Filter G1 effl.	8.0	0	2.7	81	15.0	8.5	10.9	17	15.0	4.5	7.2	51
Filter G2 effl.	6.0	0	1.7	88	14.5	8.0	10.8	18	13.5	4.0	6.5	56

[1] Filter G1 contained 2 ft. of sand; filter G2, 3 ft. 6 in. of sand.
[2] From acid N/80 permanganate in 4 hr. at 26.7° C.
[3] In 5 days at 18.3° C.

The filters were operated almost continuously until July 26 at rates up to 340 g.p.h. (U. S.) per sq. ft. Results of analysis of 6-hr. composite samples, summarized in Table IV show that there was little difference between effluents from the two filters at rates below about 275 g.p.h. per sq. ft., but at higher rates of filtration the effluent from the filter containing 3 ft. 6 in. of sand was slightly superior in quality. It is doubtful whether this slight improvement at high rates of filtration would justify using the extra depth of medium on a full-scale plant, especially as the power required for pumping would also be increased. It was thought that the greater depth might prevent a "break-through" of humus, but during experiments with medium 2 ft. deep the maximum loss of head was reached almost invariably before a break-through occurred.

TABLE V.—Comparison of Concentrations of Dissolved Oxygen in Humus Tank Effluent from Luton, England, Sewage Treatment Plant and in Effluent after Filtration through Graded Sand in Open Gravity Filters[1]

Sampling Point	Dissolved Oxygen		
	(p.p.m.)[2]	Sat (%)	Red. (%)
Humus tank effl.	4.9	52	—
Filter G1 effl.	1.6	17	67.4
Filter G2 effl.	1.1	12	77.6

[1] Filter G1 contained 2 ft. of sand; filter G2, 3 ft. 6 in. of sand.
[2] At 19° C.

Effluents from each of the filters always contained at least 10 per cent of the saturation concentration of oxygen. In the majority of samples analyzed there was slightly less dissolved oxygen in effluent from the filter containing 3 ft. 6 in. of medium than there was in effluent from the other filter (Table V).

Filtration of humus tank effluent effected a consistent reduction in the

content of organic nitrogen, but there was little evidence of oxidation of ammoniacal nitrogen.

The most efficient rate for backwashing the filter containing 3 ft. 6 in. of medium was found to be 1,200 g.p.h. (U. S.) per sq. ft., whereas a rate of only 800 g.p.h. per sq. ft. was required for the filter containing medium 2 ft. deep; the volume of wash water used was also consistently higher for the filter containing the deeper medium. This difference can probably be explained by the higher level of the wash-water drawoff above the sand in filter G2, due to a baffle which had been fitted during the first series of experiments to prevent loss of anthracite during air scouring, and also to the greater weight of sand to be lifted.

Use of Commercially Graded Sand

To investigate any difference between the sand used experimentally, which was hand graded, and the commercially graded sand intended for use in the full-scale filters at Luton, filter G2 was emptied at the end of July, 1950, and was refilled with a 2-ft. depth of the commercially graded sand. A sample submitted to sieve analysis (Table I) showed that the particle size of the commercially graded sand was finer, but less uniform than that of the hand graded sand.

The filters were operated for almost a month at rates up to 330 g.p.h. (U. S.) per sq. ft. Analysis showed that effluents from filter G2 were slightly superior to effluents from filter G1. Losses in head were almost the same in the two filters.

Full-Scale Plant

From the results of the experiments it was clear that a great improvement in the quality of a sewage effluent could be brought about by rapid filtration through sand or anthracite, and that the process would be a practicable one. The Borough of Luton, therefore, decided to install a full-scale rapid filtration plant as one of the measures for producing a sewage effluent of very

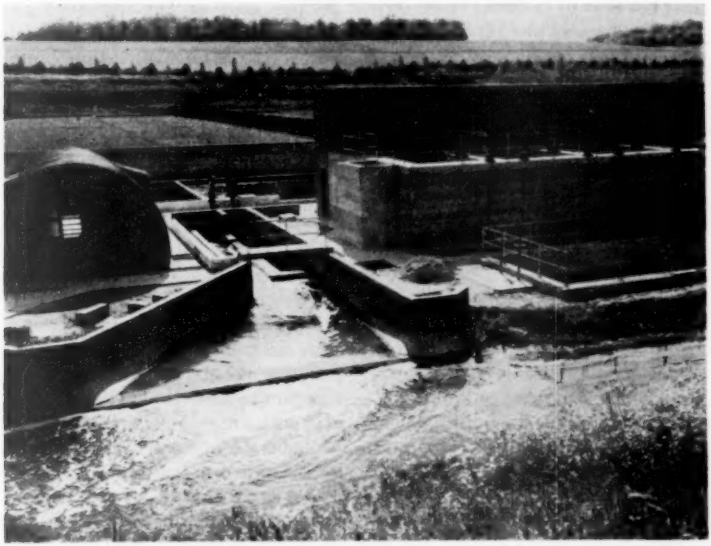

FIGURE 3.—General view of full-scale open rapid gravity filters.

FIGURE 4.—Operating gallery of full-scale open rapid gravity filters at Luton, England, sewage treatment plant.

high quality. Sand was chosen for the filtering medium, because it appeared to be stronger and more easily handled than anthracite. The full-scale plant (Figures 3 and 4) consists of a battery of 6 rapid sand filters capable of treating a total of up to 7.2 m.g.d. (U. S.) of effluent per day. The installation was put into operation in March, 1951, and since then has given very satisfactory results, producing a filtered effluent containing on an average about 4 p.p.m. suspended solids and having an average B.O.D. of about 7 p.p.m. In full-scale practice it has been found that passage through the sand filters removes practically all of the dissolved oxygen from the humus tank effluent.

Summary

Continuous operation for seven months of two semi-scale rapid gravity filters containing, respectively, 2 ft. of graded sand and 2 ft. of graded anthracite, showed that by filtration of humus tank effluent at rates of application of up to 240 g.p.h. (U. S.) per sq. ft. the content of suspended solids could be reduced, on an average, by 72 to 98 per cent, with accompanying reductions in B.O.D. and the amount of oxygen absorbed from acid permanganate of 50 to 90 and 17 to 44 per cent, respectively. There was no significant difference between the quality of effluents produced by filtration through sand and through anthracite. About 70 per cent of the dissolved oxygen present in the humus tank effluent was absorbed during filtration, but the effluents from the filters always contained at least 10 per cent of the saturation concentration of oxygen.

The filters were backwashed daily, after a preliminary scouring with air, at a rate (for sand) of 800 g.p.h. (U. S.) per sq. ft. The average loss of head during a filter run lasting 24 hr. was approximately 5.6 ft. of water. Experience with the open gravity filters indicated that, provided the filters were adequately scoured with air and backwashed at regular intervals, chlorination to keep the medium free from accumulations of organic growth would probably be unnecessary. Sand graded by a commercial supplier so as to correspond as closely as possible to the hand graded material used in the experiments could be used satisfactorily as a filtering medium.

A comparison made between filters containing 2 ft. and 3 ft. 6 in. of similarly graded sand showed that at rates below 275 g.p.h. (U. S.) per sq. ft. there was little difference in the quality of effluent produced by filtration through these two depths of medium.

A full-scale rapid sand filtration plant installed at the sewage treatment plant at Luton, England, has given very satisfactory results, approximating closely the results obtained in the pilot plant.

Acknowledgments

The authors wish to express their gratitude to the Borough of Luton, England, and to the Borough engineer and the manager and staff of the sewage treatment plant for their help and the generous facilities which made the investigation possible. This paper is published by permission of the Department of Scientific and Industrial Research, Great Britain.

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MAKE YOUR HOTEL RESERVATIONS FOR THE FSIWA SILVER ANNIVERSARY MEETING

The Hotel Statler at New York City will be the headquarters for the Federation's Twenty-Fifth Annual Meeting, to be held in October. An outstanding Silver Anniversary program is being planned for the four-day meeting.

Requests for room reservations should be addressed directly to the hotel. It should be noted that the technical program will open on Monday morning, October 6, and will close at noon on Thursday, October 9. However, the usual inspection trip will this year be scheduled for the afternoon of October 9, after the close of the meeting.

WRITE NOW FOR YOUR RESERVATIONS!

DETERGENTS AND SEPTIC TANKS*

By James E. Fuller

Dept. of Bacteriology and Public Health, University of Massachusetts, Amherst, Mass.

The tremendous increase in the use of synthetic detergents in the last decade has posed questions concerning their possible effect on the operation of septic tanks and sewage treatment plants. From time to time requests have come to the author for information concerning the effect of common household detergents on septic tank operation and efficiency. The available literature appears to be concerned primarily with sewage treatment plants, so the study reported herein was undertaken to obtain information on which answers to questions could be based with reference to septic tanks.

Rudolfs, Manganelli, and Gellman (1) investigated the effect of certain detergents on sewage treatment. They concluded that concentrations of detergents likely to be present in sewage at any one time would not be toxic to biological activities, and that the principal effects appeared to be decreased efficiency of settling tanks, with consequent increased load on trickling filters; foaming, floc agglomeration, and carry-over in activated sludge units; and reduction in gas production from sludge digestion. No direct bacteriological studies were involved. Rudolfs and Manganelli (2) further reported that anionic and nonionic types of detergents, in concentrations expected to be found in sewage, do not interfere with sewage oxidation.

In a recent review of literature (3) on sewage disposal, the reports of several authors were cited, as follows: Sciver stated that one anionic detergent had an adverse effect on sedimentation. Degens and associates reported that anaerobic fermentation of sewage sludge was not affected by less than 500 p.p.m. of several anionic and nonionic detergents. Hurley found that 50 to 75 p.p.m. of anionic detergent had no adverse effect on the effluent from a sewage treatment system. Waddams, in a general discussion, expressed his belief that, in the light of facts presented, no unmanageable problem is likely to arise from extending use of synthetic detergents.

The literature cited concerns sewage treatment plants; and, although some of the information available concerning sewage treatment might apply equally to septic tanks, there are some functional differences that made it appear desirable to undertake a study that would relate more nearly to septic tanks. The intent was to obtain information on the basis of satisfactory operation of the tanks, and it was not the intent to carry the study into the realm of basic scientific research. Some interesting phenomena were noted, however, that are worthy of such study at a later date.

Experimental Procedures

In planning the experimental work, it was obvious that full-scale septic tanks could not be used. In order to make satisfactory progress, it was necessary to study simultaneously several concentrations of several detergents, and not enough septic tanks were available for the purpose. Further, it was necessary to maintain concentrations of detergents and sewage solids at reasonably uniform levels for a 2-week holding period, which could not be done in septic tanks because

* Contribution No. 824 from the Massachusetts Agricultural Station, Amherst, Mass.

they receive and discharge contents at frequent intervals. The best procedure seemed to be to use 2-qt. glass jars, such as are used in home canning.

Raw sewage was collected from the local sewage treatment plant. To insure as uniform a quality of sewage as possible, care was taken to collect samples on week days at about the same time on each collection day. No samples were taken after a heavy rain (or thaw in the winter time) because ground water in the lines resulted in substantial dilution of the sewage. A flow meter at the treatment plant made collection possible under fairly uniform conditions of flow, and presumably of composition.

Samples were taken to the laboratory promptly after they were collected. They were mixed to make them homogeneous, and identical measured quantities were put into separate jars. Detergents were added separately to the jars in desired concentrations; untreated sewage samples served as controls.

The concentrations of detergents on which this report is based were 100 p.p.m. of all detergents, and 10 p.p.m. in some instances where it appeared that 100 p.p.m. of a detergent might affect the biological digestion of sewage solids. The use of 100 p.p.m. was based on the work of Rudolfs and associates (1), who studied the effect of detergents on B.O.D. determinations in sewage. They assumed that detergents would replace soap, which is present in domestic sewage in amounts varying from 20 to 50 p.p.m. Thus, 100 p.p.m., employed in the experiments, would exceed any concentrations of detergents likely to be present in a septic tank at any one time.

Immediately after the sewage had been put into the jars and the detergents added, the jars were stored in a dark place at about 25° C. Tests and observations were made at the beginning of each experiment, and at intervals up to two weeks of storage. The intervals, reagents, media, and methods are given under the several headings that follow.

TABLE I.—Chemical Classification of Detergents Employed[1]

Detergent	Classification
Household:	
A	No information
B	Alkyl aryl sodium sulfonate
C	Sodium salt of sulfated monoglyceride
D	Alkyl aryl sulfonate
E	Fatty alcohol sulfate
F	Sodium hexametaphosphate
G	Alkyl aryl sodium sulfonate
H	Sodium salt of fatty-acid ester of sulfoacetamide
Industrial:	
J	N-octadecyl di-sodium sulfosuccinamate
K	Aliphatic sulfate
L	Alkyl sulfonate

[1] Detergent A was a viscous fluid; the others were either powders or fine flakes.

The detergents investigated were of two groups. The first group, which represented the principal interest of the study, consisted of eight brands of detergents for household use commonly available in retail markets. The second group included three brands of detergents usually sold in wholesale quantities for industrial use, designated herein as industrial detergents. All of the detergents studied are primarily cleansing agents that are not intended to be germicidal in concentrations recommended or commonly employed. Because the author desires to present only generalized information, and not to commend or condemn any particular brand of detergent, the detergents employed are designated by letters in the data presented. A given letter refers to the same detergent throughout. The general chemical classification of the detergents employed is presented in Table I.

Visual Inspection

At intervals of two or three days the samples were inspected for turbidity,

surface scum, and settled sludge. Results of these inspections appear in Table II, in which the observations on the samples that contained detergents are compared with those on the control samples, which had none.

Turbidity

Only samples with detergents A, B, and C were more turbid than the controls, and in each instance the turbidity could have been as well described as "cloudiness" because it appeared to be caused by some reaction between the detergent and components of the sewage, rather than by suspended solids.

Scum

Only with detergent C was the layer of surface scum heavier than that on the controls, and the difference was not great in this instance.

Settled Sludge

The amount of sludge that settled out over the two-weeks storage period appeared to be about the same for the samples with detergents as for the controls.

The visual evidence indicated that the addition of detergents to the sewage did not interfere with the settling out of the suspended solids, nor was the accumulation of surface scum or sludge affected noticeably by the addition of detergents to the sewage.

Settleable Solids

The settleable solids were measured volumetrically in Imhoff cones by the technique specified in "Standard Methods" (4). All measurements were made at 14 days of storage. Large pipettes were employed to withdraw samples from between the scum and sediment layers in the jars, care being taken to disturb the scum as little as possible and the sediment not at all. Measurements from samples containing detergents were calculated as ratios to the respective control samples and are so recorded in Table II.

The amounts of settleable solids remaining in suspension after two weeks of storage were very low, which was as it should have been. With all of the household detergents the measured amounts of the solids were less than in the controls. The amounts in samples with the industrial detergents

TABLE II.—Turbidity, Surface Scum, Settled Sludge, and Settleable Solids of Sewage with Added Detergents, Compared to Control Samples without Detergents after 2 Weeks of Storage

Detergent	Turbidity[1]			Surface Scum[1]			Settled Sludge[1]			Settleable Solids Remaining in Suspension,[2] Ratio to Control
	Equal to Control	Less Than Control	Greater Than Control	Equal to Control	Less Than Control	Greater Than Control	Equal to Control	Less Than Control	Greater Than Control	
Household:										
A			+		+		+			0.14
B			+		+		+			0.60
C			+			+	+			0.58
D	+			+			+			0.59
E	+				+		+			0.35
F	+			+			+			0.62
G	+				+		+			0.29
H	+			+			+			0.70
Industrial:										
J, 10 p.p.m.	+			+			+			0.80
100 p.p.m.	+			+			+			0.95
K, 10 p.p.m.	+			+			+			0.80
100 p.p.m.	+				+		+			1.00
L, 10 p.p.m.		+			+		+			0.70
100 p.p.m.	+				+		+			0.98

[1] Determined by visual inspection.

[2] Determined with Imhoff cones.

were more nearly equal to the controls, but there was no evidence in any instance that settling out of the solids was interfered with. The household detergents appeared to facilitate the settling.

Bacteria Counts

Plates were made from the sewage when the samples were collected, and from the untreated sewage and sewage with added detergents after 14 days of storage at 25° C. Difco nutrient agar was used, and standard plating technique (4) was employed. Plates were incubated at about 25° C. for 48 hr. and then counted. The results are given in Table III, counts from sewage with detergents being expressed as ratios to the counts from the respective controls.

Not shown in Table III is the fact that all counts made after 2-week storage were substantially below those made when the sewage was first collected. The important thing appeared to be the comparison between counts from the samples containing detergents and those from the controls after the completion of the storage period, so these are the data presented. The only suggestion that bacterial survival was inhibited was in samples containing industrial detergents at 100-p.p.m. concentration. Most of the household detergents appeared definitely to encourage bacterial survival.

Coliform Bacteria

The techniques employed for detecting and differentiating coliform bacteria were those specified in "Standard Methods" (4); that is, gas production in lactose broth, colony type on eosin methylene-blue agar (EMB), and differentiation by the IMVIC tests (5). Raw sewage was inoculated into lactose broth when the samples were collected, and raw sewage and sewage with added detergents were inoculated at the end of 14-day storage. Tubes showing gas within 48 hr. were considered positive, and the most probable numbers (MPN) of coliform bacteria were calculated from the data. These results are summarized in Table III, the values for the sewage with detergents being expressed as ratios to the respective controls.

TABLE III.—Bacteria Counts and M.P.N. of Coliform Bacteria in Sewage with Detergents Added, Compared with Controls without Detergents at 2 Weeks of Storage

Detergent	Bacteria Counts, Ratio to Control[1]	Coliform Bacteria		
		M.P.N., Ratio to Control	*E. coli* (%)	Others (%)
Household:				
A	1.0	4.6		100
B	2.0	14.0		100
C	4.0	9.0		100
D	5.0	0.6		100
E	7.0	4.0		100
F	7.0	1.5		100
G	10.0	4.0		100
H	10+	1.7	17	83
Industrial:				
J, 100 p.p.m.	0.5	1.0		100
10 p.p.m.	1.0	1.0		100
K, 100 p.p.m.	0.5	3.0		100
10 p.p.m.	1.0	1.5		100
L, 100 p.p.m.	0.6	5.3	12	88
10 p.p.m.	2.6	1.5		100

[1] Control value taken as 1; values for samples with detergents expressed as ratios.

As with the bacteria counts, only the results at 14 days of storage are presented. The M.P.N. of coliform bacteria decreased gradually throughout the storage period in both controls and samples with added detergents, but the important thing seemed to be a comparison of results from the controls with those from samples with added detergents at the end of the storage period.

The order of M.P.N. values, from lowest to highest, was not the same as was the order of the total counts. Only detergent D appeared to be antagonistic to the survival of coliform bacteria. The other detergents either exhibited no noticeable effect, or else appeared to favor survival of the organisms. There was a high percentage of *Escherichia coli* among the coliform

TABLE IV.—Ammonia-N and Nitrate-N in Sewage with Detergents Added, Compared to Control Samples Without Detergents

Detergents	NH_3-N, Ratio to Control, Value on First Day							NO_3-N at 14 Days of Storage, Ratio to Control
	Days of Storage							
	1	3	5	8	10	12	15	
Control[1]	1.0	1.6	2.2	1.5	1.5	1.3	1.2	1.0
Household:								
A	1.0	1.4	1.9	2.3	2.0	1.9	1.2	1.8
B	1.3	1.6	1.6	1.7	1.7	1.5	1.4	2.2
C	1.0	1.0	1.0	1.2	1.2	2.0	3.0	1.4
D	1.0	1.2	2.7	1.8	1.6	1.5	1.2	1.3
E	0.9	1.3	2.6	1.3	1.2	1.4	1.4	3.0
F	0.8	0.8	0.9	1.0	1.0	1.1	0.6	1.5
G	0.6	1.1	2.5	1.9	1.3	1.0	0.9	2.6
H	1.4	1.5	3.0	1.3	1.1	1.3	1.3	1.0
Industrial:								
J, 10 p.p.m.	0.8	1.0	1.1	1.0	1.0	1.1	1.0	0.7
100 p.p.m.	0.8	1.0	1.1	1.1	1.1	1.2	1.0	0.7
K, 10 p.p.m.	0.6	0.8	0.5	0.6	0.0	0.0	0.0	1.0
100 p.p.m.	0.6	0.5	0.5	0.2	0.0	0.0	0.0	1.0
L, 10 p.p.m.	0.6	0.6	0.2	0.2	0.1	0.0	0.0	1.0
100 p.p.m.	0.4	0.5	0.3	0.2	0.1	0.0	0.0	1.0

[1] No detergent.

bacteria recovered when the sewage samples were collected, but at the end of the storage period *E. coli* was not recovered from the controls and was recovered only from samples with detergents H and L. The disappearance of *E. coli* from the several samples was consistent with results reported by Fuller and Litsky (6) from studies with sewage sludge.

Ammonia

Evolution of ammonia is an indicator of proteolytic digestion of sewage solids and was employed for that purpose in this study. The testing procedure employed was that specified in "Standard Methods" (4). Results were calculated as p.p.m. of ammonia. The control samples were tested at the time of collection, and the controls and the samples with detergents added were tested for two weeks at intervals of two or three days. The results are shown in Table IV, in which all measurements are stated as ratios to the control value on the first day.

With the exception of detergents C and F, the results with the household detergents followed the general trend of the control, and no interference with protein decomposition was indicated. In the sample with detergent C, ammonia production was relatively retarded for the first few days, and then gained momentum and attained a ratio higher than with the other detergents. Ammonification in the sample with detergent F remained at a low level throughout the storage period. The industrial detergents appeared to retard ammonification, and hence might be regarded as hindering the decomposition of sewage solids.

Nitrates

The object of this part of the study was not the determination of nitrifying activity as such, but rather was a comparison of the nitrate content of sewage to which detergents had been added with that of the control samples. The method employed for the tests was the phenoldisulfonic acid method as specified in "Standard Methods" (4). Tests were made at the end of 14-day storage. Results were calculated as

p.p.m. N, and are expressed in Table IV as ratios of the control value.

Only in samples containing detergent J was there less nitrate-nitrogen than in the controls. The other two industrial detergents, and household detergent H, gave results approximately equal to those of the controls, whereas the other household detergents gave higher values.

Hydrogen Sulfide

Hydrogen sulfide production was another measure employed to indicate proteolytic decomposition of sewage solids by bacteria. The hydrogen sulfide was determined qualitatively by means of lead acetate paper, which is a standard bacteriological test. Some quantitative estimate was possible by observing the intensity of the blackening of the paper and by observing the length of time that blackening persisted. Strips of the lead acetate paper were suspended in the sample jars in the air space just above the fluid level. The paper was put into the jars at the beginning of the storage period, then removed after each 24 hr. and fresh paper was put in its place. The exposed strips of the paper were examined for positive blackening, indicating hydrogen sulfide, and for the degree of blackening. The data from this part of the study appear in Table V, in which the intensity of the reaction is indicated by single or double plus marks.

In all samples with household detergents, the rate of hydrogen sulfide production was speeded up to give more intense reactions than those of the controls, and the reaction seemed to terminate in most of them before the end of the storage period. The reactions in the samples with the industrial detergents were more active than those in the controls for the first few days, after which they tapered off to about the same level as the controls for the remainder of the storage period. There was no evidence that any of the detergents hindered hydrogen sulfide production, and a definite stimulus and speeding up of the reaction was indicated with certain of the detergents.

TABLE V.—Hydrogen Sulfide Production in Sewage Samples with Detergents Added, Compared to Control Samples without Detergents[1]

Detergents	Days of Storage					
	2	4	7	9	11	14
Control[2]	+	+	+	+	+	−
Household:						
A	++	++	++	+	+	−
B	+	++	++	++	++	+
C	++	++	++	+	−	−
D	++	++	++	+	−	−
E	++	++	++	++	+	−
F	++	++	++	+	−	−
G	++	++	++	++	+	−
H	++	++	++	+	−	−
Industrial:						
J, 10 p.p.m.	+	+	+	+	+	+
100 p.p.m.	+	+	+	+	+	+
K, 10 p.p.m.	++	++	+	+	+	+
100 p.p.m.	++	++	+	+	+	+
L, 10 p.p.m.	++	++	+	+	+	+
100 p.p.m.	++	++	+	+	+	+

[1] H_2S detected with lead acetate paper; degree of blackening indicated by + or ++.
[2] No detergent.

Discussion

In reporting this investigation, the author is aware that the data obtained are significant only within the limits of the experimental conditions, and that these conditions were different from those existing in either a septic tank or a sewage treatment plant. The sewage content of a septic tank or of a sewage treatment plant is changing constantly, with new sewage coming in and effluent being discharged. These factors would make it impossible to maintain uniform concentrations of detergents, so an artificial system had to be set up. There were two other reasons why full-scale operating septic tanks could not be employed: it would be impractical in any case, and impossible in the present situation, to have available a sufficient number of such tanks to permit the study of the desired number and concentrations of detergents within a reasonable time limit; there would be an inevitable lack of uniformity among septic tanks in the amount and kind of sewage

passing through them. Deviations from the normal are necessary, however, in many fields of research.

The information derived from this study indicates that there is no apparent need for a householder to be apprehensive lest the discharge of common household detergents into a septic tank should interfere with its normal functioning. It must be admitted that the results could be considered negative in the sense that they did not indicate any detrimental effects from adding the detergents to sewage. For that reason the experiments were repeated a sufficient number of times to make the data as valid as possible.

One factor that could not be investigated under the experimental conditions is the possible cumulative effect of repeated additions of detergents to septic tanks over a long period of time. In the author's opinion, the only effective way in which that information can be obtained is from septic tanks in practical operation for the treatment of household sewage. It should be mentioned, also, that the data apply to the detergents investigated, but not necessarily to others of different composition or to new products that may come on the market in the future. It would be impossible to be all-inclusive in a study of this kind, so the detergents employed were those most commonly sold and used in the section of the country in which the study was made.

Results obtained with the household detergents differed from those with the industrial brands in that the latter gave lower total bacteria counts and appeared to retard ammonification. This suggests that the industrial detergents would be more likely than the household brands to interfere with the proper functioning of septic tanks, but the risk would not be great under ordinary conditions.

Summary

1. The effect of non-germicidal detergents on the biological digestion of sewage was studied under laboratory conditions. Eight commonly-sold household detergents and three industrial detergents were investigated.

2. Observations or tests were made on turbidity, scum and sludge accumulation, settleable solids, total bacteria counts, numbers and types of coliform bacteria, ammonification, nitrate content, and hydrogen sulfide production.

3. There was no evidence that household detergents, in concentrations likely to be present in sewage at any given time, would be detrimental to the proper functioning of septic tanks. There were indications that the industrial detergents would be somewhat more likely to be detrimental, but the risk does not appear to be of serious consequence.

Acknowledgments

The author wishes to acknowledge the contributions of J. L. Lapuck and R. C. Canning, graduate students in bacteriology at the University of Massachusetts, who assisted in the laboratory work.

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Industrial Wastes

1951 INDUSTRIAL WASTES FORUM *

ROLF ELIASSEN, *Leader*

Professor of Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Chairman Eliassen:—For some time, those concerned with industrial wastes have been discussing the design of plants and processes, but haven't paid too much attention to the operational aspect of industrial wastes treatment. This aspect is one which should interest the Federation. As individual Sewage Works and Industrial Wastes Associations we want to attract operating personnel because we feel we can help them, and through forums like this we can be of greater service to them.

The day-to-day operations present different problems from those arising in the design of treatment plants. We must hear from people with experience in operation; from men who practice constant surveillance of their operations so that the everyday control of losses becomes a very important aspect of industrial wastes. The first speaker is one who really has had a problem of loss control.

Everyday Control of Losses

A. C. Hyde, E. I. du Pont de Nemours, Belle, W. Va.:—The Belle works of the du Pont Company is a very large chemical manufacturing plant located at Belle, W. Va., on the Kanawha River. The Kanawha River flows through a narrow valley and in a 20-mi. stretch supports a large share of the nation's chemical industry.

The Belle works has grown from a modest beginning, 25 years ago, to its present giant size. Pollution paralleled growth, and the rapid expansion during World War II pointed up the necessity for drastic reduction in pollution loading to the river.

The first look at the problem was a pretty discouraging one. Cooling water and process wastes are combined in all the many manufacturing operations. More than 250 m.g. of mixed effluent are discharged daily through 42 outfalls to the river. As neither water nor effluents are metered, measuring sewer flows presented a major problem in the beginning. To further complicate the sewer measurement and sampling problem, most of the sewers are 20 to 25 ft. underground and discharge 15 to 18 ft. under the surface of the river. That condition came about by reason of the Army Engineers building dams and deepening the river by 18 ft., inundating the then existing outlets.

The initial survey of the problem revealed more than 400 individual sources of pollution; some, of course, much larger than others. The bulk of the wastes are organic in nature.

Space requirements, toxicity, and shock loading made it apparent from the first that conventional biological treatment methods could not be applied. The receiving stream presents quite a story in itself and is not ideally suited as a waste disposal medium. It has wide flow fluctuations, varying from a low of 1,500 to a high of 30,000 sec.-ft. in flood flows, with a mean summer average in the neighborhood of

* From transcript, 24th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; St. Paul, Minn.; October 8–11, 1951.

2,500 to 3,000. The flow is controlled over many miles by hydroelectric installations. During critically low flows, the entire flow of the river may be shut off for 5 to 8 hr. to conserve water for peak power demands; that is when the dilution water also is needed most. On several occasions, the Army Engineers have manipulated the stream pretty severely through operation of the flood control dams. The purpose seemed to be the testing of pontoon bridges during all types of flows. For their purposes, it was very convenient, because they could virtually shut off the river for one test and then create flash flood for other tests. Wastes, however, are produced more or less evenly over the 24-hr. day, so such flow patterns are difficult to cope with. So much for the dark side of the problem.

The West Virginia State Water Commission surveyed the Kanawha River and, after finding it very heavily polluted, signified its desire of improving the stream to a Class B rating. That calls for an average of not less than 4 p.p.m. D.O. and not more than 6 p.p.m. B.O.D. Our loading had to be reduced 80 per cent in order to meet the initial requirements; we also understand that it must be even further reduced in the future.

A waste disposal group was formed directly under staff management. Throughout its operation to date it has received strong management support in all matters. The purpose of this group is to correlate all pollution abatement activities in the plant. Actual research and development work is carried on by what we call a technical or research group. Responsibility for reducing pollution and keeping it in control resides in the areas creating the nuisances. It should be pointed out that one of the initial steps in reviewing the problem was trying to break the pollution load into various categories. The two major breakdowns turned out to be wastes controllable by improved housekeeping, improved morale, or just plain cleaning up; and those that had to be corrected by actual engineering development. It was felt (just was an educated guess) that approximately 30 per cent of it could be controlled by the operating men themselves. That guess has been pretty well borne out by actual experience.

After surveying the many angles of the problem, it became evident that in most cases reductions would have to be made at the source by improved control and housekeeping, engineering changes to equipment or processes wherever possible or feasible, and, the above failing to be applicable, development of novel treatment devices.

Strenuous efforts were made to educate all personnel, from the plant manager down to the laborers, on pollution in general. By means of talks to groups and individuals, written memoranda, and any other means presenting itself, people had to be taught what the many new terms (such as D.O., B.O.D., and chemical oxygen consumed) meant, what the effects of various wastes were on the receiving stream, etc. In short, an effort was made to create 4,000 pollution specialists in the plant. A major portion of the success or failure of our type of program rests with the people who actually turn the valves. To date, results have been most gratifying.

Several treatment devices have either been installed or are in design. A gas-fired furnace, known to us as a "thermal decomposition unit," destroys approximately 20,000 lb. of B.O.D. per day. Approximately 7 g.p.m. of a mixed organic acid solution is sprayed into the furnace, and complete decomposition takes place. A small retention reservoir of about 1.5-m.g. capacity is used to store some wastes, such as concentrated still heels, mashes, etc., that cannot be incinerated and would normally create peak discharge loadings. The wastes so stored are discharged during winter floods

under Commission supervision. Lack of space for adequate reservoir capacity limits this type of disposal; 1.5-m.g. storage is very little in comparison to the total wastes. In addition, these wastes must be such that they can be loaded into tank wagons for transportation, as the reservoir is nearly a mile distant from the plant. A catalytic oxidation unit * developed by the plant technical group is being ordered. When that is in operation, it will eliminate another 25,000 lb. of B.O.D. per day.

At this stage, the 80 per cent reduction mentioned earlier is in sight and we are holding our ground by means of a method of daily control that is quite successful, considering the many variables involved. A reliable, continuous automatic sewer sampler was developed and one was installed on each sewer carrying any appreciable amount of pollution. A 24-hr. composite sample from each sampler is delivered to the control laboratory the first thing each morning. A chemical oxidation by dichromate is run immediately and the results are made available to the operating areas involved. An aliquot of the original sample is placed each day in a composite bottle kept in a deep-freeze refrigerator. A 7-day composite so made is analyzed for B.O.D. each week.

There has been a great deal of controversy at various meetings and in the literature about the value of the B.O.D. analysis. In our case, it is felt to be very reputable; we have had a high degree of success with it. Some of the analyses have been out of line, but on the whole the test has been quite reliable and has given good results.

In general, the chemical oxygen consumed value checks the B.O.D. reasonably close on most sewers; in others, however, the check is poor. It has been found, nevertheless, that a reasonably constant relationship can be established between B.O.D. and chemical oxygen consumed. As an example, in one case, in one of the most highly polluted sewers, the chemical oxygen consumed is quite generally 30 per cent of the B.O.D. The chemical oxygen consumed test is then used as a rapid method of control and has proven its value many times over. The results are available early in the day, and any analysis out of line with the established normal must be explained by the operating area involved. This method has frequently located leaking equipment or process errors, which normally would have shown themselves much later in calculated yield or inventory loss. Operating supervision has come to look upon the sewer sampling and analysis system as a valuable aid to operating control. In some major operating areas impressive yield improvements have accompanied the pollution abatement program and it is very doubtful that the operating people would return to the "old days" even if they were permitted to do so. The weekly composite B.O.D. serves as a record.

The river is sampled daily and the dissolved oxygen determined. A weekly B.O.D. analysis is used for arriving at a loading determination. Each week the pollution control group determines the plant pollution load, both from the river samples and from the total of the various plant effluents. As a general rule, the check between the two is remarkably close.

It should be mentioned that a satisfactory method for measuring sewer flows was developed. This consists of a sodium or potassium dilution method. Sewer flow determinations have been made at a number of river temperatures and graphs plotted. At any given river temperature and normal plant production, the flow in any sewer is known. This is important, as the operating people watch their sewer loadings and from day to day speak in terms of pounds of B.O.D. discharged.

* See THIS JOURNAL, **24**, 3, 288 (Mar., 1952).

If they are to keep faith, they must be given concrete tools with which to work.

Another valuable tool in control is river forecasting and daily or hourly knowledge of river flow. By cooperation with the U.S. Weather Bureau, a teletype message is received early each morning giving rainfall that has fallen throughout the three-state drainage area translated into expected river flow for the following 24-hr. period. Rain forecasted or expected to fall during the next 24 hr. is translated into expected flow in 48 hr. In short, we know the existing river flow and are quite positive of the river flow that will come within the next 48 hr., because that is based on rain that has already fallen. We also have a pretty fair forecast of the rain that will fall for the next 24 hr., and that can be translated into flow for the succeeding 48 hr.

The current flow is known from a U.S.G.S. continuous gaging station at Kanawha Falls and readings on the hydroelectric turbines. From this data, a daily instruction sheet is published and given wide distribution throughout the plant. The sheet contains the current river flow and that expected for the next two days. Any indication of higher than normal water carries with it the suggestion that maintenance or other programs that might cause greater than normal wastes should be planned. If a decrease in flow is forecast, it is accompanied by proper warnings. River temperature at the plant and dissolved oxygen 7 mi. below the plant are recorded on the sheet. In this way, each man is permitted to watch pollution conditions in the river himself. Should anyone make an unauthorized discharge, he is able to see the results the next day. The sheet has short comments about river conditions if any condition warrants comment. The interest engendered has many plant people watching the river. A typical comment might be to the effect that an oil slick observed the previous day was found to have originated above the plant, or that it had been traced to a leak or accidental spill in the plant. If a serious low-flow period is passed without damage to fish or to the dissolved oxygen level, people in general are complimented. If fish are noticed to be in trouble, our people are so warned. Anything of interest that can be confined to several sentences may be included. Over a period of years, a whole plant of pollution specialists can be painlessly created. This daily note has become a plant institution.

The note also carries an instruction as to the disposition of certain controllable wastes, such as still heels, equipment washes, etc. The instruction says that they must be impounded in the reservoir, or, with intermediate flows, certain discharges may go to the river, and in others, that large dumpings may be tolerated during high flows, provided they are scheduled. All dumpings other than continuous routine ones must be cleared with the pollution control office. Because thousands of analyses have established the pollution value of every known discharge, a reasonable prognosis of its effect on the river can be made. Each morning a safe river loading, based on analysis, is calculated. The normal daily plant load is known; therefore, additional safe loading can be computed.

As a typical example, an operating foreman calls and says his glycol batch still heel will be ready for disposal 16 hr. later. Assuming that the daily instruction sheet didn't tell him to impound all wastes and that discharges can be scheduled, he is asked the volume and B.O.D. load. The pollution control group knows this, but they also want the operating foreman to know it. After giving the required information, he is told to discharge it over 12 hr., or 5 hr., or whatever time fits. He also is given the hours to use and is

told that a certain other area is using the time before him. In some cases, to prevent losing production, he will make a deal to trade hours with a man in another area who is discharging. These trades are all cleared with the pollution control office. In any event, only a given number of pounds of B.O.D. per hour are discharged. On a number of occasions, unaccountable foams or slicks have been skimmed from the river as a sample and the nature of the material determined in the laboratory. The offending area is then notified. We are proud of the feeling that the above tactic is no longer used very often. It is a source of pride and pleasure to see the degree of interest and cooperation shown by the plant people as a whole.

The benefits readily noticeable as a result of the program are of much value. There is a distinct improvement in employee morale and a feeling of pride that the company has spent effort and money and has accomplished a considerable degree of river cleanup. They understand, however, that much still must be done. The method of systematic sampling and analysis is used as a dependable tool in area operation and has often detected leaks and faults. In many areas, yield improvements have been attributed to pollution abatement techniques. Last, but not least, "the proof of the pudding" has been the improved river conditions now existing; rough fish flourish and game fish are staging a comeback. Tribute should be paid to the splendid spirit of cooperation, help, and understanding given throughout the work on this problem by the state control authorities of West Virginia.

E. M. Van Patten, American Maize Products Company, Robey, Ind.:— American Maize Products Company produces corn products by the wet milling process. The materials are handled in wet suspension from the beginning raw material up to the final end product. Therefore, the company's industrial waste potential is very great; in 1943, for example, the plant had an industrial waste loading of all sewage effluents of roughly 400,000 population equivalent. In addition, the plant is located on the south shore of Lake Michigan, therefore the pollution problem is very pressing.

The problem was attacked in much the same way as the du Pont people approached their work at the West Virginia plant. An initial survey of plant wastes was made to classify all possible avenues of wastes, their magnitude, and general volume. Such a survey was found to be basic and fundamental to solving the entire problem. Incidentally, this waste survey and initial study consumed a period of some 6 to 8 months of intensive study.

The survey was originally done by the research organization group. After all the various avenues of wastes had been more or less established, a permanent group was set up for daily routine analysis and sampling and metering equipment was established on all important trade waste flows. It was then determined that the best way to eliminate these wastes would be to replace faulty equipment, modernize processes wherever possible, and attempt to solve the problem by eliminating the waste at the source, rather than to develop fancy treatment processes.

An attempt was made to cut down water use wherever possible, and to cut down solids losses on the heavy evaporation equipment. As previously mentioned, all of the products are handled from the initial process (steeping of the raw material, corn) in wet suspension, up until the final steps of the process (such as corn syrup concentration, corn sugar crystallization, and, of course, starch drying). Considerable volumes of water are used in this process—about 1.5 m.g.d. We also tried to re-use so-called waste effluents wherever possible. In

other words, every possible waste material was studied to determine if it really was a waste. It was found that by precise production scheduling it was possible to eliminate some process waters and reduce the volumes of certain waters that had been a very large contributing factor to the over-all waste load. General processes were streamlined, simplified, and controlled as much as possible to eliminate the human element.

That was a rather difficult task to undertake. The plant is equipped with some 15 evaporator pans, ranging from single- to three-phase evaporators. A major part of the trade waste was from entrained solids lost in the operation of this concentrating equipment. After the major portion of this concentrating equipment had been modernized and replaced, it was found that if the solids losses could be held to 170 p.p.m., the B.O.D. loading or the loading potential from such sources of waste would be within tolerable bounds.

The operating personnel of heavy concentrating equipment could either make or break the entire program. So, a very thorough educational program was inaugurated. Personal instruction of all the operating foremen was undertaken to impress upon them the need for care. At first, it was a rather bitter pill, and the pollution control personnel weren't too popular. However, after the process workers and the foremen finally grasped the problem, they became interested and we got splendid cooperation from all personnel involved. In fact, almost every one of the 1,000 employees might be considered to be a waste "specialist."

Now the foremen will call the waste abatement group and let us know what is happening, and what is liable to take place during any given 8-hr. shift. If they have some shock load of waste that is impossible for them to avoid, such as spillage, they will call us up and ask us what to do with that particular waste.

Another interesting sidelight to this educational approach is that the plant phone intercommunication system is equipped with a tape recorder. So, the waste abatement group staged frequent half-hour discussions on the tape recorder. Every time anyone picked up a phone and dialed the tape recorder number, they were greeted by a little talk on trade waste abatement.

Detailed discussion of the entire process is beyond the scope of this discussion, but we do concur in the main with what Mr. Hyde has told of du Pont's approach to the problem. We found, of course, that our wastes are not organic chemicals, so it was possible to use the major portion of what was originally thought to be waste material and put it back in process and, by doing so, to increase our overall plant yield by about 1 per cent plant solids. That doesn't seem like much, but figuring on a yearly basis and with the present price of corn, it roughly meant a savings of some $175,000 to $200,000, which helped to amortize the initial program of equipment modernization, a program which cost roughly $850,000 to $1,000,000.

Acknowledgment should be made to Carl B. Carpenter, Superintendent of the Anderson, Ind., sewage treatment plant, who was of great help in the initial planning. The same holds true for the personnel of the Indiana Stream Pollution Control Board.

Chairman Eliassen:—To what population equivalent have you reduced your wastes?

Mr. Van Patten:—The plant's initial population equivalent was roughly 400,000 people, which is fairly large. Over a period of six years, we have managed to reduce that initial population equivalent to, roughly, 28,000 people. That is the total biological loading of all the plant effluents.

Chairman Eliassen:—That is a terrific reduction—400,000 to 28,000.

Mr. Van Patten:—I might add that most of the American Maize Product Company reduction was through the re-use of waters, and the savings of solids losses. Very little, if any, pretreatment was used. We do have some steep water condensation, which is a mixture of the corn processing water and the initial steeping water to soften the shell of the corn for preliminary milling. The condensate from the evaporation of this water did carry an appreciable loading potential, most of which was in the form of solid matter, alcohol, formaldehyde, etc. We did pretreat some of these condensates very roughly by passing them countercurrently through an air stream in what we call a scrubber (essentially an open beer still). By this method of treatment we were able to reduce the total loading potential of the steep water condensate by between 45 and 55 per cent.

P. M. Teeple, State Dept. of Health, Jacksonville, Fla.:—Mr. Hyde, could you give a brief outline of how the sewer flow is determined chemically?

Mr. Hyde:—Parshall flumes or devices of that type could not be used because the sewers are 25 ft. underground. What we do is to feed sodium chloride or potassium chloride, whichever seems to be applicable, with a small, constant-rate feeder. Samples are taken, by means of a continuous sampler, for a period of 30 min. Then the salt addition is started and perhaps 300 lb. of salt is fed over a given period of time (maybe 30 min.) Samples again are taken every 5 min. and then analyzed by means of a flame photometer for sodium chloride or potassium chloride, whichever has been favorable. That method has been quite reliable. We tried dilution of dyes, and we tried stream anemometers, Pitot tubes, and any of the various devices that you might think of, but we found the sodium or potassium dilution method highly reliable. Proper mixing is assured by using a 500-ft. run of turbulent flow, which exists in all the plant sewers.

W. W. Sanderson, New York State Dept. of Health, Albany, N. Y.:—Have you tried using conductivity measurements?

Mr. Hyde:—We made just a brief attempt because we have such a "dog's breakfast" in the sewers. The concentration varies so widely that the conductivity method didn't seem to offer itself as being very practical. That would be a very good method if you had more or less constant types of discharge, but ours vary quite a bit in some of the sewers.

K. S. Watson, General Electric Co., Schenectady, N. Y.:—What would you say the accuracy was on these particular measurements of flow?

Mr. Hyde:—That's a tough question. We can check our analyses within a few per cent, one analysis from another, or we can check a sewer flow one day and then check it perhaps a week later with the same river conditions, same river temperature, and be within, let's say, 5 per cent. The over-all criterion for thinking we are pretty good on this method of analysis is that the total B.O.D. loadings for all of the effluents, balanced against the B.O.D. analysis of the river, will usually check within around 10 per cent, which is quite good; that is, we couldn't be too far off on our flows to have that happen. The flow of water will vary by approximately 30 per cent from winter to summer; it will increase 30 per cent.

Mr. Teeple:—Mr. Hyde, if B.O.D. measurements are taken daily, are you computing 1-day, 2-day or 5-day B.O.D.'s for your standard of comparisons?

Mr. Hyde:—We use 5-day B.O.D.'s entirely, the chemical oxygen consumed being in most cases substituted for the B.O.D.

Lynn Enslow, Editor, Water and Sewage Works Magazine:—Is that a proportionate sampling program?

Mr. Hyde:—It is not, although it is

adaptable to being proportionate. It is not proportionate because we have no method of continuous measurement of sewer flow. In one case, we have a Parshall flume serving a recent addition to the plant; in that case the sampler is proportionate.

Mr. Enslow:—How do you figure the stream loading if it isn't proportionate? There must be some record of volume to arrive at the values given.

Mr. Hyde:—That's what I mentioned. We do it by the sodium or potassium diluting method. We have determined what the flow will be based on the river temperature. In other words, as the river water temperature goes up, it naturally will take more water for cooling temperatures. If the river temperature is 70° F., we know that a given sewer handles 5 m.g.d. If it is 75°, it might be 7.5 m.g.d. Based on river temperature, we know the flow in the sewer, assuming, of course, that the operation is normal in any particular area. That flow might change if units are shut down, but it is the function of the control people in that particular area to keep us posted on any shutting off of water.

Fred E. Reimers, Chemical Engineer, Merck & Co.:—What retention time is provided by the 1.5-m.g. equalization basin?

Mr. Hyde:—The 1.5-m.g. retention basin is not an equalization basin. All of the wastes go directly from the source to the river, except those few that we manage to catch and put in tank wagons and carry to the retention reservoir, where they are held perhaps 6 to 9 months, until high water. An interesting sidelight is that the flood did not materialize in 1951. We had a particularly dry summer, so we managed to wheedle a $500,000 alcohol storage tank from plant management.

Operation of Anaerobic Treatment Units

Chairman Eliassen:—The next subject is the operation of anaerobic treatment units. We have heard much in our discussions over the past many years about the operation of aerobic units, but anaerobic units are coming to the fore in the treatment of industrial wastes, just as they have with domestic sewage.

W. J. Fullen, Geo. A. Hormel & Co., Austin, Minn.:—The 24-hr. anaerobic fermentation of packinghouse waste is being conducted by the Geo. A. Hormel & Co. in a pilot plant located at Austin, Minn. B.O.D. reductions of 93 to 96 per cent are being repeatedly obtained. The anaerobic effluents seem to be readily oxidized on a conventional filter.

The pilot plant consists of six units: a holding tank for raw waste, a digester, a sludge separation tank, a flocculator, a clarifier constructed along the lines of an Imhoff tank, and a rock filter.

The digester is equipped with a pump that circulates its contents through an external heat exchanger at the rate of once every 47 min. A thermostat effectively holds the temperature at 90° to 92° F. Little heat is required, as the temperature of the raw waste is 85° to 105° F. and all external units are insulated.

The digester was started with sludge obtained from the primary and secondary digesters at the Austin municipal sewage treatment plant. Considerable time is required to acclimate a sludge to a foreign substrate. In this case 131 days were required before the digester could be operated diurnally. This acclimated sludge has been aptly termed an "activated anaerobic sludge." The operation is to pump an amount of raw waste at such a rate that the digester will have handled a load in 24 hr. equivalent to the cubical content of the digester.

The overflow from the digester goes to the sludge separation unit, where about 75 per cent of the sludge rises rapidly and the remainder settles. The bottom sludge is returned at frequent

intervals to the holding tank receiving the raw waste. The top layer of sludge is returned to the holding tank once or twice daily.

The digested waste is drained from the sludge separation unit continuously. This partially clarified effluent, drawn off from the layer between the top and bottom sludge, goes to the flocculation tank and thence to the clarifier. The sludge in the clarifier is pumped back to the holding tank. A portion of the clarifier effluent is fed to the filter. Detention times in the various units are as follows: digester, 1 day; sludge separation, 7.5 hr.; flocculator, 11 to 12 min.; and Imhoff clarifier, 33 min.

This method of operation gave the following results: raw waste fed, 22,743 cu. ft.; time, 27 days; average digester detention time, 1 day; and B.O.D. removed per cubic ft. of digester capacity per day, 0.095 lb. Analytical results, in p.p.m., were as follows:

Determination	Raw Waste	Anaer. Effl.	Change (%)
Total solids	6,400	4,920	− 23
Volatile	1,770	552	− 68
Susp. solids	873	174	− 80
Total N	137	114	− 17
NH_3-N	26	105	+313
Org.-N	111	7	− 93
B.O.D., 5-day	1,610	73	− 96

These performance figures were obtained by calculating the weights into and out of the digester. Daily analyses were taken on the raw waste and the final anaerobic effluent.

It would be expected to find an accumulation of sludge in the system. In 19 days, after the unit was equipped to return all settled sludge back to the digester, 50 cu. ft. of sludge was removed. During the 19-day period 15,350 cu. ft. of raw waste was fed. The removed sludge amounted to 0.33 per cent of the raw waste fed. It is too early to state that this will be a standard procedure.

It has been stated that the volume of sludge in the digester could be from 12.5 to 50 per cent. We like to carry between 35 to 40 per cent by volume, determined as follows:

A sample removed from the digester is placed in a 1-l. graduate. After 15 min. under quiescent conditions, the total volume of top and bottom sludge is noted. This should be between 35 and 40 per cent, of which 75 per cent will rise rapidly and continue to rise for about 12 hr., concentrating to about one-half its original volume. Gas production is very active in this thickened sludge. Also, because 20 to 25 per cent of this thickened layer will extend above the initial water level, it is possible to take advantage of this property to remove a very thick top sludge. The liquid level is carried about 4 to 6 in. above the drawoff troughs so that the rising sludge comes up between the troughs and thickens. By lowering the level, a very thick sludge is washed back to the starting, or holding, tank.

Tests indicate the sludge separation tank removes about 85 per cent of the suspended solids coming from the digester. The Imhoff clarifier removes about 13 per cent, leaving 2 per cent going over the filter.

No figures are available on the amount of gas produced on the test shown. Former tests show that 9.5 to 10.5 cu. ft. are produced per pound of volatile matter added to the digester. All gas measurements have been of the gas produced in the digester only; no attempt has been made to measure gas produced in other units, although the sludge separation tank is being covered and gas measurement will be attempted.

The tests of the action of the clarified anaerobic effluent on standard filter media are indicative rather than conclusive. The filter presently in use is a small one (oil-drum size). It is 26

in. deep, has a surface of 2.76 sq. ft., and contains 6.3 cu. ft. of rock. This media is hand-picked igneous rock graded to 1½- to 2½-in. size.

B.O.D. tests were started after about 10 days of filter operation, when a growth was noted on the media. It is interesting to note that nitrites started to form after the filter had been in operation only a few days. The filter is being dosed with 235 g.p.d., equivalent to 3.7 m.g.a.d.

Little data have been accumulated on filter performance, as the filter has only been operating for about six weeks. However, the last 10 days showed the following results:

The filter influent showed an average B.O.D. of 64 p.p.m., a pH of 7.55, and an alkalinity of 790 p.p.m. This amounts to only 866 lb. of B.O.D. per acre-foot. The filter effluent showed a B.O.D. of 31 p.p.m. (a reduction of 51 per cent), a pH of 8.03, and an alkalinity of 715 p.p.m.

In conclusion, there is admittedly much more work necessary before this project could go into large-scale plant. However, it does seem to be fairly certain that packinghouse waste with a B.O.D. content of 1,200 to 2,000 p.p.m. can be digested in 24 hr. with an efficiency of 90 to 95 per cent removal of B.O.D.

Fred Nelson, Manager, Western Sanitary Division, The Dorr Company, Los Angeles, Calif.:—While I was employed in Chicago it occurred to me that corn canning waste probably could be economically treated by anaerobic methods. As a result of that, through arrangements with the Lakeside Packing Company, Plainview, Minn., we conducted 19 days of test work. Unfortunately, we were limited to that length of time partly due to a delay in getting started, and then when a start was made there were only 19 days of operation before a heavy frost made the corn unfit for canning.

During that time, an attempt was made to run tests on both mesophilic and thermophilic digestion. The thermophilic operation was not successful, primarily due to the fact that it was not possible to develop the proper culture in that length of time. In conducting the tests, 50-gal. drums about 23 in. in diameter and 34 in. in depth, were used. These were submerged in a water bath heated by waste steam from the plant, and kept at a fairly constant temperature.

The tank was seeded with supernatant liquor from the digester at the city sewage treatment plant. Actually, it was sludge, because the tank was badly overloaded and the supernatant liquor had suspended solids of 6.4 per cent, the pH was 7.4, and the temperature was 75° F. The seeding material was permitted to remain in the tank one day before sampling; the pH had dropped to 7.2, the temperature had risen to 98° F., and the B.O.D. was 5,775 p.p.m.

Flow tests made the previous season showed about 15 gal. of waste per case of No. 2 cans, exclusive of the cooling water. This figure was lower than generally encountered in corn canning, with the average probably being near 25 gal. per case. The B.O.D. at Plainview was high, but appeared to be about in line with other canneries processing corn, considering the smaller quantity of waste; that is, it is higher than the average in p.p.m., but in total pounds of B.O.D. it appeared to be in line.

During the initial stages of the experiments no attempt was made to withdraw a supernatant liquor from the tank because it was assumed that, due to the colloidal nature of the raw waste, there would be very little separation of the solids from the water in the digestion tank. However, this proved to be erroneous, as it was possible to get a very good supernatant liquor. Unfortunately, time did not permit doing as much work in this regard as was desired.

It should be noted that the tests were started using a 15-day digestion period, but this was subsequently reduced to 10 and, finally, 5 days. The pH was maintained well above 7.0 without the addition of chemicals for both the 10- and 15-day periods, but had a tendency to drop when it was reduced to 5 days. Possibly digestion would have continued at the lower pH, but rather than take a chance on having the process upset, small amounts of lime were added from time to time to hold the pH at or above 7.0.

The time of conducting the tests was too short to determine the shortest digestion period, but it would appear to be somewhere between 5 and 10 days.

A. M. Buswell, Illinois Water Survey, Urbana, Ill.:—I would like to ask Mr. Fullen whether he has any analysis of the gas?

Mr. Fullen:—We do not have any ourselves, but the Minnesota State Board of Health ran some. It varied quite a lot and ran as high as 80 per cent methane, although there was considerable carbon dioxide at times.

Dr. Buswell:—One would expect a much higher methane content from material such as you were testing than from other types of waste. The carbon dioxide is very much more soluble, of course, and with the methane being substantially insoluble, methane contents of 80 per cent or better are expected with this kind of waste. It is a source of great gratification, having worked with anaerobic fermentation for many years, to find that at least some of the laboratory results are recognized. We have plenty of results showing 85 to 90 per cent gasification of pure compounds, such as sugars, fats, and proteins, within 24 hr. As a matter of fact, when running theoretical studies on pure compounds, unless the gas yield amounted to 85 per cent of the theoretical from the amount fed the day before we knew that the culture was not in the best condition and something had to be done about it.

The amount of loading reported by Mr. Fullen is about 90 lb. per day of volatile solids, with 10 cu. ft. per pound volatile yield of gas, which gives approximately 1 cu. ft. of gas per cubic foot of digester per day.

Mr. Fullen:—The value is about 10 B.t.u. per pound of raw waste fed.

Dr. Buswell:—Sewage works operators are more familiar with the yield per cubic foot. This sort of material, which digests 90 per cent or better in 24 hr., should theoretically yield about 15 cu. ft., or sometimes 20 cu. ft., per pound of volatile matter, because this volatile matter is practically 100 per cent digestible. It appears to me that in this particular setup digestion is going on throughout the three tanks and no doubt an appreciable amount of gas is lost in the floating sludge when it is pumped and also from actual evolution in the holding tank and the settling tank.

Mr. Fullen:—We definitely know that. I have stirred that rising sludge at night and lit it, and it would flash all over the top of the tank. Dr. Buswell said we should have more gas. Dr. Roundtree, from New Zealand, wrote that after having seen our barrel tests he had his laboratory make some tests. He reported twice the amount of gas that we were getting; however, he might be taking all of the paunch waste and a lot of the material we screen out. Incidentally, he held up the construction of a plant for the treatment of wastes from four packinghouses and is building an 80,000-gal. pilot plant.

Chairman Eliassen:—We talk in terms of high-rate trickling filters with B.O.D. loadings of 60 to 70 lb. B.O.D. per day per 1,000 cu. ft.; and of activated sludge plants with loadings of 20 to 40 lb., or whatever figure we can get out of them. The thing that surprised me was the B.O.D. loading of 95 lb. per 1,000 cu. ft. per day. Can we expect more than that, Dr. Buswell? Is that a good loading figure?

Dr. Buswell:—With heavier wastes you can expect considerably more than the loading you mentioned.

Chairman Eliassen:—What do you consider heavy sludge?

Dr. Buswell:—I am thinking here of wastes of 10,000 p.p.m. or more B.O.D. as having 1 to 3 per cent solids. With such heavy material much more efficiency can be obtained from anaerobic fermentation because you are not limited by volume. Where the waste contains only 1,000 or 2,000 p.p.m. B.O.D., it must flow through at too high a rate and just washes the material right on through unless a larger tank and a longer detention period is used.

W. S. Wise, Chief Engineer, State Water Commission, Hartford, Conn.:—What is the optimum temperature in the digester?

Mr. Fullen:—When the works was first started, a number of different temperatures were tried. A temperature between 90° to 92° F. was taken because the raw waste was just about that temperature. There seem to be three essentials provided; the waste contains phosphorus, plenty of nitrogen, and plenty of temperature.

R. M. Babcock, State Board of Health, Lincoln, Nebr.:—What about the odor problem in connection with the plant described?

Mr. Fullen:—The odor isn't what I call very bad. More hydrogen sulfide is noticed with prolonged digestion than with a 1-day fermentation.

Dr. Buswell:—With respect to this odor, we have had some experience at Crystal Lake, Ill. The effluent from the digester is discharged submerged to the effluent from a trickling filter. The pilot plant that was operated at Carthage, Ohio, on distillery wastes was operated in a similar way. The odor directly from the digester has the typical odor of septic sewage, but it was discharged submerged into a tank which was receiving the back circulation from the trickling filter. This treatment is always started with some back circulation, which will completely take care of the hydrogen sulfide. The hydrogen sulfide is oxidized before reaching the filter distributor.

Mr. Enslow:—Would it be possible to recover ammonia from all of the waste?

Mr. Fullen:—I doubt it very much. I don't know how you would go about it. If you mean aeration and absorption in sulfuric acid, we haven't tried that.

Chairman Eliassen:—There are a lot of questions like that that can be asked. Adoption of such a process finally resolves itself into a question of economics.

Operation of Aerobic Treatment Units

Chairman Eliassen:—Any mention of anaerobic treatment facilities necessitates, also, mention of aerobic units—and *vice versa.* Many times wastes are not concentrated enough to rely on anaerobic digestion as an economical treatment, and we must of necessity go to aerobic processing. The trickling filter is, of course, the most common aerobic process in industrial wastes treatment for removing organic matter from industrial wastes. Davidson * described the design of a trickling filter for distillery wastes, especially where feedstuff recovery is practiced. Now that the plant has been in operation for two or three years we would like to find out if he still thinks well of his design. In starting a full-scale operation, we have to start with pilot plants; it is important that we, as designing engineers, learn from the operator what we have to look out for and how our design criteria compare with operating results.

A. B. Davidson, Schenley Distillers, Inc., Cincinnati, Ohio:—The trickling filter may be termed the old reliable standby for treating various types of

* Davidson, A. B., "Treatment of Distillery Wastes." THIS JOURNAL, **22**, 5, 654 (May, 1950).

wastes. Recently it has been adapted to many different types, although the design, of course, is influenced by the wastes to be treated. The filter has a few advantages over other processes. One of the main advantages is that it will take shock loads. Another is that it requires a minimum of supervision, which sometimes is valuable in small plants. It also has a couple of disadvantages. One is the high cost. For an industry that is rather important, because the filter is a capital asset fully taxable, whereas a higher operational cost of treatment isn't quite as important with the present tax structure. Another disadvantage is that it requires a breaking-in period.

We find that the trickling filter quite readily handles distillery wastes, which might be considered typical organic wastes. In comparing distillery wastes to other wastes, it is rather like the comparison the old Kentucky Colonel gave when asked about a certain brand of whiskey. He said, "Son, all whiskey is good, but some of it is gooder than the rest." All wastes are bad, and some are "badder" than the rest, with distillery wastes being classed as one of the "badder." Reference here is made to what is meant by the common term "distillery waste," which is the distillery slop or spent mash. It is treated and recovered in our dryhouses, as mentioned many times before. This material has a high B.O.D. (about 30,000 to 40,000 p.p.m.), but the dryhouse recovery process removes about 98 per cent of that load.

The material under discussion is the leftover—the squeal of the pig. These wastes (evaporator condensate, cooling tower overflow, spills, etc.) have an average B.O.D. of about 550, a pH of about 5, and a temperature of about 114° F. Passage through the high-rate filters removes an average of about 93 per cent of the B.O.D. load, reduces the pH to 7.5, and reduces the temperature to about 75° F.

In discussing filters used for industrial wastes, it would seem possible to confine oneself almost entirely to high-rate filters. They have proven more adaptable, in general, and the rate of recirculation can be varied according to the flow and strength of waste. We happen to use a 4:1 recirculation ratio. The high B.O.D. load involved changes the water loading concept somewhat. In other words, the stronger the waste, the lower the water loading and the less flushing action. It seems that most industries are going to large-sized media to compensate for this. We use 3- to 4-in. media and have had very little trouble with ponding. Another variation in the design which doesn't seem to affect the filter operation is whether or not to enclose the media with a wall. One Schenley treatment plant has a concrete wall around it, simply because the filter was put in a slope of the hill and we had to keep the dirt back. Another has a loosely woven fence holding the stone. Still another doesn't have the fence, wall, or anything; just the slope of the stone. There are no apparent variations in results from the three filters; they all average about the same reductions. Of course, the one without any wall support at all is cheaper than the one with the concrete wall.

As regards ponding, I have never been able to tell too much by the growth on the filters. It does seem to get thicker and more luxuriant with higher loading, although on occasions it is very thin. We have observed anywhere from ⅛ to ½ in. on the top of the beds. At other times it can barely be seen, but apparently the results stay about the same. Of course, if you do get heavy slime growth, there is some danger of ponding with finer stone. We had one filter where the stone was put in with the fine segregated in one spot and there was trouble with ponding at that one spot. However, it was rather easy to stop; we

just sprinkled a little HTH on the ponding area and it disappeared.

Another advantage of high-rate filters is their ability to resist toxicity and some degree of change in pH. Our wastes do have a slight amount of copper in them, but we have never noticed any effect on the action of the filter, and the pH does change occasionally from a low of 5 up to 7.5. In one case, an operator dumped a tank of caustic cleaning solution into the sewer, instead of putting it into the caustic recovery system, which raised the pH to about 11.5 and cleaned all the film off the filter.

One problem we ran into in starting up a filter was excessive speed of the distributor arms. Sometimes the arms revolved rather rapidly, setting up a rocking motion, which of course was hard on the bearings. We found it very easy to remedy by taking one of the sprays off the back of the arm and putting it on the front so that it pushed against the direction of rotation. This slowed it down rather effectively.

In ordinary operation the filter is just like a municipal filter; the arms require flushing, the orifices require cleaning, occasional painting is necessary, as well as cleaning of the oil or the mercury.

A high-rate filter is not supposed to have filter flies to any degree, but with a strong industrial waste and the low hydraulic loading, there might be a few. We have flies on all of our filters. and all the way through the dead of winter, due to the high temperature of the waste. They have not been prevalent enough to be a nuisance, but they can be observed around the sides.

Incidentally, where a final polish is necessary on the effluents, a sand filter will do the job as well as anything.

One thing that helps in the operation of high-rate filter plants is some type of automatic sampling system. There are many types of automatic samplers on the market. They are good, but costly. We have devised a system which is not too accurate, but does serve the purpose. Pipes or copper tubing are run from the sampling points with ¾- to 1½-in. lines equipped with solenoid valves. The tubes empty over a funnel with a drip rod so that a portion of the liquid drips into the funnel and on into the sample crock. The solenoids are on a time clock so that they will kick in every 30 or 60 min. The result is a fairly decent composite sample. Of course it isn't composited according to flow, but with a fairly constant flow it is not too bad.

In conclusion trickling filters can be used for practically all organic wastes. They are very reliable, seldom get out of order, and require a minimum of attention.

Chairman Eliassen:—We hear of trickling filter loading rates up to probably 100 lb. of B.O.D. per 1,000 cu. ft. Some people may say 60 to 70 lb. should be the limiting load. What we are striving for, both in pilot-plant operation and in the research laboratory, is economy of design. Activated sludge hasn't been able to handle such high capacities. Perhaps that is because we haven't known enough about the fundamentals of the activated sludge process. Sawyer and Helmers have done considerable work on this at M.I.T. under a research grant from the National Institutes of Health. Because there are not many high-rate activated sludge units in operation, Mr. Helmers has been asked to discuss some of the things that have been learned in the laboratory and which might be applied to the design and operation of activated sludge plants with the possibility of getting higher rates of loading and, therefore, making the process more attractive for use by industry.

E. N. Helmers, Engineering Service Division, E. I. du Pont de Nemours and Co., Wilmington, Del.:—As Dr. Eliassen mentioned, if activated sludge is to compete seriously with trickling

filters in the industrial wastes field, the loadings will certainly have to be improved. There are a number of industrial trickling filter installations designed to handle 60, 70, or 80 lb. B.O.D. per 1,000 cu. ft. Activated sludge plants are usually conservatively designed, with loadings down around 20 to 30 lb. B.O.D. per 1,000 cu. ft. of aeration capacity. Activated sludge apparently does have certain advantages over trickling filters, however; the operator has more control over the operating variables—he can control his rate of return sludge and the amount of air supply. This cannot be done quite so readily with trickling filters. The control possible with activated sludge enables an operator to obtain a more uniform quality of effluent under different conditions of temperature and under a variety of B.O.D. loadings.

The laboratory studies at M.I.T. were conducted to investigate some of these problems of activated sludge treatment. The results showed that industrial wastes and industrial waste-sewage mixtures could be treated at loadings up to 70 and more pounds per 1,000 cu. ft. of aeration capacity per day without reduction in efficiency. The B.O.D. reductions ran well above 90 per cent. Wastes could be handled at these loadings if sludge bulking could be prevented. Sludge bulking, then, is one of the primary problems in operating an activated sludge plant at the higher loadings.

Sludge bulking has been investigated by numerous people, and several plants are operating successfully at higher loadings by using different means of controlling this condition. Krause, at Peoria, Ill., is operating at high loadings with domestic sewage containing a high percentage of industrial wastes by returning properly conditioned digested sludge to the aerator. I believe Hatfield also is using this system at Decatur, Ill., at loadings in the neighborhood of 60 to 70 lb. B.O.D. per 1,000 cu. ft. per day. In the laboratory we did not use this method, but resorted to chlorination with 2 to 5 p.p.m. for control of sludge bulking.

Supplying nutritional deficiencies by nitrogen and phosphorus supplementation also aided in controlling sludge bulking. Nitrogen and phosphorus also affect the rate of B.O.D. removal. An interesting observation was that a point is reached in the addition of nitrogen where addition of another increment does not do much good. This amount of nitrogen has been designated as the "critical nitrogen requirement"; that is, the nitrogen that must be supplied to give the maximum rate of B.O.D. reduction under the conditions of treatment. It so happens that this critical nitrogen requirement is somewhat less than what is called the "maximum nitrogen requirement," which is the maximum amount of nitrogen that will be utilized by the sludge if there is an excess available. Additional nitrogen just comes out as inorganic nitrogen in the effluent.

This raises the question as to the best way of determining whether or not the activated sludge plant is operating with a nutritional deficiency. If there is residual inorganic nitrogen in the effluent, the plant is probably operating with a nitrogen excess. However, because the critical nitrogen requirements are somewhat less than the maximum, it is possible to operate at a slight deficiency and still get optimum purification. The inorganic nitrogen content of the effluent may indicate operation at a deficiency, but it does not measure the magnitude of the deficiency. A better measure of the magnitude of the nutritional deficiency is the nitrogen content of the sludge.

This series of experiments also revealed several other points. The activated sludge process responded immediately to temperature fluctuations by decreased rates of B.O.D. removal,

but this could be counteracted by returning greater amounts of sludge.

An attempt was also made to determine the effect of pH variation. Between pH 6 and 9.5, the pH of the feed had little effect on the stabilization efficiency. Below pH 6 the rate fell off quite rapidly. Some feed mixtures were used with pH as high as 10.5 and alkalinities of 800 to 1,000 p.p.m., with only a slight decrease in purification rate. The high pH decreased rapidly during the stabilization and the process was not affected very much.

In conclusion, it should be noted that much of the work concerning temperature and pH variation was carried out at M.I.T. after I left, and I am reporting on some information received from Dr. Sawyer by correspondence.

George E. Gagne, Henry B. Steeg & Associates, Indianapolis, Ind.:—Mr. Helmers mentioned the use of nitrogen and phosphorus in connection with the control of sludge bulking. I wonder if he would explain his theory as to how that came about?

Mr. Helmers:—I have no theory as to why nitrogen and phosphorus may control the bulking of sludge. I will say, though, that the effect in our experiments—the rate at which we got results in controlling sludge bulking by adding nitrogen and phosphorus—was rather slow. With a serious sludge bulking problem, I am not sure that the addition of nitrogen and phosphorus is the entire solution. In fact, in some of the experiments under discussion it was not, because we had to add chlorine. But supplementation did seem to help.

Chairman Eliassen:—Mr. Davidson, what was your loading in pounds of B.O.D. per 1,000 cu. ft. per day?

Mr. Davidson:—It was 0.75 lb. per cu. yd.

L. S. Kraus, Superintendent, Greater Peoria (Ill.) Sanitary District:—This matter of expression of loadings has been used rather loosely, and it seems to me that in every case we should take into account all of the plant capacity that is utilized for the treatment accomplished, and we should also relate that loading to efficiency of treatment. It appears to me that the loadings reported by Mr. Fullen are not one-day digester loadings, but something considerably longer than that, possibly two or more days, because certain volumes were involved that were not computed in the loading factors. Likewise, in multiple-stage trickling filter operation, where recirculation is employed, how does one arrive at a loading? Is it the input loading to the filter, or the input loading to the process? Is the recirculation taken into account? And so on. There are many factors in expressing loadings which can be misleading. For instance, the Peoria plant has what we term a nitrifying aeration tank, to which we add digested sludge and activated sludge, and which is considered a part of the activated sludge process. Our loadings get up to monthly averages in the order of 55 lb. of B.O.D. per 1,000 cu. ft. of total aeration tank volume. However, if we only consider the aeration tanks, then we have loadings in on the order of 80 and peaks of more than 100; but these values are not significant, in my opinion. The total volumes that are involved should be used in expressing a loading.

Mr. Reimers:—Mr. Davidson, how did B.O.D. reduction in the summertime compare with reduction obtained during the winter?

Mr. Davidson:—Actually, we notice very little significance, probably due to the temperature of the waste, which averages about 114° F. and sometimes gets as high as 140°. So the temperature in the trickling filter is fairly constant, varying only 10° or 15° each way.

C. H. Connell, University of Texas Medical School, Galveston, Tex.:—Mr. Davidson said he observed very little

difference in efficiency on the basis of the thickness of film and appearance of the film. Was that on the basis of the superficial rocks or full bed depth?

Mr. Davidson:—That was on the basis of the rock on the top of the filter and on the walls, where we didn't have a concrete wall.

Application of Submerged Combustion

Chairman Eliassen:—The next subject is the approach of the chemical engineer and his unit operations in the handling of industrial wastes. We have been reading more and more about evaporation as the solution to industrial wastes problems. It may be very easy to prescribe evaporation, but the cost is high. We have to arrive at some basis of economy *versus* efficiency of this particular unit operation. There are several ways of accomplishing evaporation, and we are interested in hearing of some new methods which are indeed worthy of appraisal.

The first speaker on this subject is going to tell something about submerged combustion (because I am sure most of us don't know what it looks like) and some of its applications.

W. I. Weisman, Ozark-Mahoning Co., Tulsa, Okla.:—The submerged combustion method of evaporation seems to be very well suited for the concentration of some waste solutions, and in those cases may provide distinct advantages as compared to other types of evaporators. An explanation of the principles of submerged combustion will enable an understanding of why this is true and should be of aid in determining whether or not submerged combustion evaporation might apply to a specific problem.

Submerged combustion has been defined as "burning a gaseous fuel in a special burner submerged completely beneath the surface of a liquid." To accomplish this, it is necessary that the gaseous fuel and the combustion air be introduced to the burner in such a way as to avoid combustion until they are well submerged and then to maintain the flame at this point. In the burner manufactured by the Ozark-Mahoning Company, the air and gas are mixed before being introduced to the burner. Combustion of the air-gas mixture prior to entering the burner is prevented by maintaining a velocity in the leader tube to the burner which will exceed the flame velocity or rate of flame propagation for this air-gas mixture. In the burner itself, the mixture velocity falls below the flame velocity so that combustion can take place.

This can be understood better by referring to a diagram of a typical submerged combustion unit (Figure 1), which consists of the following components:

1. A positive pressure-type blower to deliver the necessary combustion air to the burner.
2. The burner assembly, which includes an electrical igniter, the air-gas mixing device, and interconnecting piping.
3. A tank which holds the liquid being processed, and a suitable vapor stack.

Not shown in Figure 1 is the fourth component, the control panel, on which are mounted gages, switches, and instruments. If manual control is adequate, only rather simple instruments are needed; if fully automatic controls are desired, the instrumentation may be fairly complex, depending on the variable used to control heat output.

As can be seen, the transfer of heat is direct from the products of combustion to the solution. The gases leave the burner in the form of many small bubbles, which provide a tremendous heat transfer surface. Hence, the transfer of heat is very rapid and complete. From experience it is known that if the burner is completely submerged the gases will leave the solution, cooled to the same temperature

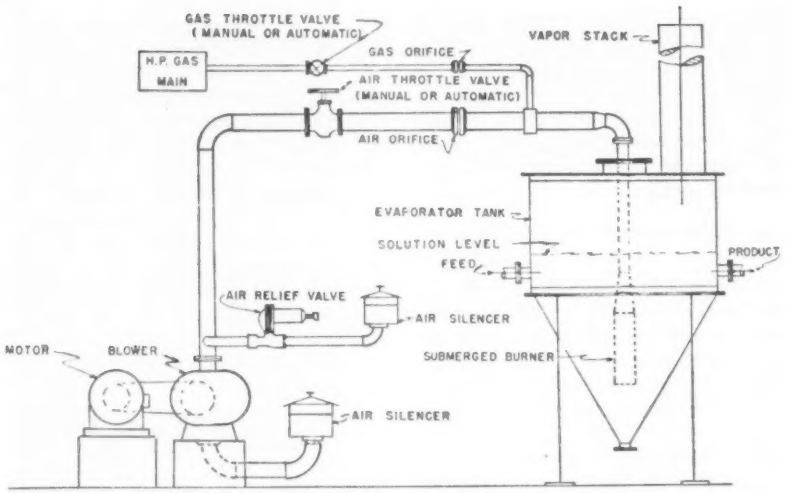

FIGURE 1.—Schematic sketch of typical submerged combustion installation.

as the solution. Obviously, under these conditions high thermal efficiencies must result.

There are several types of solutions which are difficult to evaporate in conventional tube and shell evaporators. One of these types is the solution that forms scale on the tubes. Scale decreases the rate of heat transfer and results in a loss of capacity. Frequent and expensive shutdowns may be needed to remove scale. In a submerged combustion evaporator these characteristics of the solution do not affect the capacity or operation, because there are no heat transfer surfaces on which scale can form.

Another type of solution which may result in a low coefficient of heat transfer through tubes is one of high viscosity. Submerged combustion can handle these solutions without difficulty in the usual evaporation problem, but cannot, of course, be used to dry a solid of high moisture content.

Solutions with high boiling points also are difficult to evaporate in vacuum evaporators, but present no problem in submerged combustion evaporation. In evaporating these solutions by submerged combustion, some slight decrease in thermal efficiency can be expected because the combustion gases are discharged at a higher temperature and radiation losses are higher.

Corrosive solutions also present a problem for tube evaporators because expensive alloys usually are required for tubes and replacement may be frequent and costly. In contrast, only the burner of a submerged combustion unit is subject to the severest corrosive conditions and a graphite burner design has been developed which indicates long life in many corrosive solutions.

Many waste solutions which might be considered for concentration by evaporation fall into one or more of the categories mentioned. For example, the present shortage of sulfur is making all users of sulfuric acid aware of the possibility of reclaiming waste acids for re-use. Many petroleum refineries make it a practice to concentrate waste alkylation acid and sludge acid from treatment of lubricating oils. Work has been done on some of these acids and it appears that submerged combustion may have some advantages in concentrating them.

Another spent acid under study is waste pickle liquor. It appears that waste pickle liquor from a continuous pickler usually will be strong enough in acid so that the value of the recovered acid will about equal the cost of recovery. In locations where it is necessary to neutralize waste pickle liquor with lime, the savings in neutralization costs probably would make attractive the recovery of even rather weak pickle liquors. There is keen interest in this application of submerged combustion at present and no doubt installations will be made for this service.

One of the submerged combustion installations that has been made in the waste disposal field is that of the Texsun Citrus Exchange, Weslaco, Tex. It has been described in detail,* so only a brief outline of the process is included here. Citrus peel liquors contain about 6 per cent of sugars and can be concentrated to a molasses of value as a stock food. The peel liquors, however, contain salts which scale badly on heat transfer surfaces. At Texsun, a double effect vacuum evaporator was in service, but because of the severe scaling, operating was difficult and expensive. Pilot plant work with a submerged burner revealed that a "heat shock" treatment followed by settling could remove the scale-forming constituents and permit trouble-free evaporation in the conventional equipment.

Another interesting installation is located at the plant of Newport Industries, Oakdale, La. One of their processes uses zinc chloride as a catalyst, which ends up in a waste discharge. The concentration of zinc chloride in the waste is only 1.5 to 2 per cent, but this is sufficiently high to eliminate the possibility of discharge to the nearby Caleasieu River. The zinc is toxic to fish and the chloride is very objectional to rice growers, who use the river water downstream for irrigating rice fields. Evaporation of the water produces a concentrated zinc chloride solution, which probably can be sold to recover part of the expense of disposal.

The possibility of making a salable product is one good reason for considering evaporation as a waste disposal method. Submerged combustion evaporators are being supplied to a large chemical company for a job that started out simply as a disposal problem, but actually will prove to be a profitable investment. It involves the recovery of an organic acid, which previously went down the drain. The company is installing these units at three locations and each will earn a substantial return.

There is another application of submerged combustion which might be of interest, although it does not involve evaporation. A submerged burner is an excellent producer of carbon dioxide because of its ease of operation, simplicity, and controllability. Some may be familiar with submerged combustion recarbonators, as used in many municipal water plants for recarbonating lime-softened waters. In the same way, such a unit can be used to neutralize alkaline wastes before discharge. Actually, in most locations carbon dioxide is the cheapest acid available, and submerged combustion is the most convenient way of producing it. One installation has been made for treatment of dye wastes at the Opelika, Ala., plant of Pepperell Manufacturing Company, and has been giving the desired results. Another installation is being made for the Champlin Refining Company, Enid, Okla., to reduce a high alkalinity in the waste water.

The final choice of the type of evaporator to be used for any concen-

* Burdick, E. M., Duncan, W. E., and Anderson, C. O., "Application of Submerged Combustion to the Processing of Citrus Waste Products." *Chem. Eng. Prog.*, **45**, 539 (Sept., 1949).

trating problem will be determined by the local conditions within the plant in question. Submerged combustion can handle solutions which are difficult to concentrate by other methods and, in addition, probably involves less capital investment and lower maintenance costs than other types of evaporators of comparable capacity. The main reason for the lower capital costs is that steam generating facilities are not required. Submerged combustion has the disadvantage that in areas where gaseous fuels are expensive the cost of fuel may be quite high compared to multiple-effect or other types of evaporators. Therefore, in considering the choice of equipment for an evaporation problem a thorough study of cost factors should be made before the final decision is reached regarding the type of equipment to be used.

Evaporation of Calcium-Base Sulfite Waste Liquor

Chairman Eliassen:—Some wastes seem to defy economical treatment by normal processes. Mr. Weisman mentioned a couple, with waste sulfite liquor being one of the most difficult problems as far as treatment by current processes is concerned. It is also a tremendous problem in stream pollution abatement. At a recent conclave of the American Chemical Society in New York, one of the speakers predicted that within about 10 years waste sulfite liquor would be insignificant as far as a stream pollutant is concerned. When this speaker was questioned from the floor, he stated that as a result of evaporation, and particularly the evaporation of the calcium-base sulfite liquors which are our biggest problems, we would see the disappearance of this waste sulfite liquor now dumped into the stream. This process is not hypothetical, but has been quite highly developed in Sweden; I understand there are something like 15 plants there. It also is beginning to come into prominence here, with one plant under construction in Wisconsin, and a couple more reportedly approved by that State Department of Health. This is good news for stream pollution control authorities, and we would like to have some first-hand information on the method. I understand that Mr. Jacoby, our next speaker, has just returned from Sweden, where he has seen plants of this type, and is now working on some in Wisconsin.

Harold E. Jacoby, Process Equipment Division, General American Transportation Corp., New York, N. Y.:—The manufacture of pulp by the sulfite process depends on the dissolving of the non-cellulose portion of the wood by means of an acid bisulfite solution, usually calcium bisulfite. The yield of desired cellulose is roughly 50 per cent by weight of the dry wood entering the digester. This leaves about 50 per cent of the original wood in the form of a spent liquor from the digester.

The source of the disposal problem is the spent liquor. Ordinarily and previously, the liquor was discarded to the sewer. Quantitatively, a mill producing about 100 tons of pulp per day discharges more than 100 tons of dry solids in solution to the sewer, with about 90 tons being organic material, roughly 20 per cent of which constitutes sugary materials. Basically, the material is ligno-sulfonates and sugary materials.

There have been tremendous sums of money spent on ways and means of developing a practical process for getting out the possibly useful materials contained in the spent liquor. So far, in the United States particularly, there has been no process which could be generally acceptable to all mills, although there are a few processes in operation today which do handle spent sulfite liquor.

Because of the many valuable constituents in this liquor, many attempts were made to get at them. In Europe,

particularly, the obtaining of ethyl alcohol from the sugary constituents had become more or less general practice. Most of us are familiar with the condition of the ethyl alcohol market in this country and how it has fluctuated and what competitive sources there are. As a result, I believe there are only one or two mills in the country which are producing alcohol from the spent sulfite liquor.

An attempt has also been made to recover tanning materials from spent sulfite liquor. The results have been more or less mediocre, as other materials form much better tanning compounds. Adhesives and plastics have found some sort of a market, and there are a few plants in operation which devote their liquor to the production of materials for adhesives and plastics. This may be a market of considerable importance in the future, but so far it is just being felt out. In short, although products can be derived from spent sulfite liquor, marketing difficulties have resulted.

Very frequently, the expensive equipment involved increases the cost of production. In many cases where pollution enters the picture the attack has been mainly toward the sugary materials. As these represent only about 20 to 30 per cent of the organic content of the liquor, the pollution abatement problem hasn't been solved by that approach.

Furthermore, some of the steps frequently required evaporation, for which the available equipment until rather recently was not of a practical nature, and rendered the process practically impossible to begin with. The basic difficulty is that the solution is saturated with calcium sulfate. Immediately on starting evaporation of such liquor, serious fouling of the heating surface occurs. If the operation is a continuous one, this fouling presents a very difficult situation. Until recently, the existence of these scaling compounds was a stumbling block. When pollution abatement became necessary, something had to be done about the situation. As a result, the Sulfite Pulp Manufacturers' Research League in Wisconsin sent representatives to Sweden to study the installations there.

The Swedish approach was somewhat different from ours, as they are primarily interested in the fuel value contained in the liquor. As a consequence, they have developed certain equipment which has been successful over a number of years, and our people decided to study it as thoroughly as they could. They came back with the answer that as far as they were concerned evaporation of sulfite liquor was a practical solution in Sweden, and it could be adapted here.

Although it may sound as though we are backing into evaporation and burning as a means of treating the sulfite disposal problem, I think it should be noted that in the kraft industry, which is a much larger pulping operation than sulfite is today, the recovery of liquor by washing, evaporation, and burning is a standard practice. Not only is heat recovered from the organics, but also there is a tremendous chemical recovery as well. The sulfite industry today is attempting to go after chemical recovery also. However, the trend at present is to stick with calcium base and to go after pollution abatement only and thereby relieve the pressure from enforcement bodies.

At any rate, the point is that by means of evaporation each mill can handle its problem; each can serve as its own customer, because it can use all the heat that is produced by the evaporation and subsequent burning towards its total steam requirements in pulp producing. Roughly speaking, at least a 35 per cent fuel savings is achievable.

The recovery operation works about like this: It is practicable to recover about 75 per cent of the solids in a

solution of about 10 per cent by weight. This is usually evaporated to about 60 per cent solids and then is introduced into a furnace. On this basis, with about 2,400 lb. of dry solids per ton of pulp, and 75 per cent recovery, about 1,800 lb. of dry solids are recovered per ton of pulp, which is the equivalent of an evaporation of 15,000 lb. of water per ton of pulp. In a more or less typical installation, the evaporator would require about 4,300 lb. of steam to accomplish that amount of evaporation. The subsequent burning will produce about 9,000 lb. of steam. In other words, there is a net of about 4,700 lb. of steam produced per ton of pulp, which is a considerable saving in a mill producing 150 tons of pulp per day, a fair average for the Wisconsin mills.

How is this evaporation accomplished? It was mentioned previously that evaporation, until recently, had been a stumbling block. The basic approach is that calcium sulfate is soluble in water to a slight extent and is more soluble in an acid water than it is in a neutral water. In the evaporation of the spent sulfite liquor, an acid condensate is produced, due to the fact that a certain amount of SO_2 is driven out during evaporation.

There are also certain organic acids that contribute as well. This condensate is used to dissolve the scale on the heating surface. The usual type of evaporator is represented by a tube bundle and will have, for example, steam condensing on the outside of the heating surface and liquor boiling on the inside of the heating surface. That relationship is fixed. The new type of machine, the so-called Rosenblad channel switching unit, which has been adopted from Swedish practice, consists of a series of sandwiched flat plates spaced at short intervals one from the other. The sandwiched plates present equal cross-section areas from one channel to the next so that if boiling liquor is present in alternate channels and steam is condensing in alternate channels, equal cross-sectional areas are presented to both the steam side and the liquor side. As evaporation proceeds, scale will form on the channels subject to liquor. After a suitable interval of time, the equipment is shut down. The liquor is drained, and what was the condensing steam side becomes the boiling liquor side and *vice-versa*. Condensate is recycled with the steam to produce a very wet steam, the object of the condensate being to wash the surfaces which had become scaled with liquor. In short, the machine can continually evaporate and continually dissolve the scale as it is formed.

The problem is not merely one of eliminating scale from the heating surface itself. Apparently a case of supersaturation probably exists which causes scale to continue to form not only on the heating surface, but also on the vessels of the equipment, in the pipelines, in the pumps and valves, and so on. By a similar device of switching the liquor system with the condensate system, any scale which developed in the equipment is simply washed off.

Reverting to the applications of this design, in Sweden there are a number of mills that have been operating up to six years, but on the basis of a 6-day work week. With the 7-day work week used in the United States, a careful study had to be made of the limitations under continuous operation. It is believed that those factors are now known. For example, certain temperature limitations must be applied to this liquor because it is subject to carbonization when overheated. If the liquor carbonizes, the condensate washing system cannot be applied. As a consequence, evaporators must be operated within a temperature range wherein only scale is formed on the heating surface and no carbonization of the material occurs.

The maintenance problems are no

greater or less than they are with any other standard type of evaporator. The usual types of pumps, valves, and controls are employed. The drawback, of course, is that stainless materials are used due to the acid nature of the liquor, and Type 316 stainless steel is the usual form of construction. However, the result is felt to be a practical solution of the sulfite waste problem. The liquor can be evaporated successfully and continuously, and can be burned to produce enough heat to effect a substantial savings in fuel requirements and go a long way toward paying the cost of the equipment. Chemical recovery will probably develop much farther than it has, resulting in a net saving in the recovery operation.

That about covers the situation as it exists, except that three mills in Wisconsin have equipment on order for this purpose. Two machines are in operation out on the West Coast, and it is expected that there will be a considerable development in this field both in Wisconsin and on the West Coast within the next few years.

Mr. Teeple:—I would like to ask one question that has to do with the alternate scale formation and reduction or disposition of that scale. What is the chemical or biological nature of the material that would go out of the equipment into the stream?

Mr. Jacoby:—If we could effect complete collection of the liquor drained from one set of passages in the switching interval, the only material that would be discharged would be calcium sulfate. However, due to the fact that a certain amount of liquor must adhere to the walls of the equipment, during the initial starting of the next step subsequent to switching there is a short interval of time, usually a matter of minutes, in which a small amount of liquor itself is lost. As in most evaporators, entrainment can be a problem, and entrainment separators are normally supplied which will keep the losses down to less than 0.1 per cent of the total solids introduced initially. In the type of equipment being discussed, a small amount of liquor is lost due to the necessary washing of liquor which adhered to the surfaces; but basically the wash water will be a calcium sulfate solution.

Dr. Buswell:—Has the waste sulfite liquor fed to the evaporators been treated by the Howard process for the recovery of sulfites, or is it drawn directly from the bottom of the digester?

Mr. Jacoby:—This is liquor directly as it is received.

Dr. Buswell:—The saving of sulfur and sulfite is thrown overboard?

Mr. Jacoby:—No, there will certainly be an attempt to retain any amount of sulfur that possibly can be recovered. That is a problem apart from the evaporation step, and even in those cases where evaporators have not as yet been installed, equipment is going in for recovering sulfur from blow gases and the liquor itself.

Chairman Eliassen:—I would like to ask Mr. Weisman if any thought has been given to the possibility of using oil in submerged combustion?

Mr. Weisman:—Yes, there has been a great deal of work done on that problem, and we think that we are getting close to an answer. It is necessary to vaporize the oil into the combustion air stream, and there are various types of vaporizers on the market. One was finally found that seems to have considerable promise. There has been some pilot plant work done on it, but to date no commercial installations have been made. It does require a rather high-grade fuel oil, something like a No. 2 fuel oil, so that it still may be a rather expensive fuel compared to gas.

BIOCHEMICAL OXIDATION OF DAIRY WASTES

III. Failure of Sodium Nitrate as a Source of Oxygen *

By Nandor Porges, Janet B. Pepinsky, Lenore Jasewicz, and Sam R. Hoover

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In the course of investigations on the biochemical oxidation of dairy waste, the use of sodium nitrate as a source of oxygen in disposal of dairy waste was suggested. Lagoons (7) and streams (4) have shown beneficial effects from nitrate. Such treatment would be desirable for the prevention of offensive odors associated with anaerobic conditions when mechanical failure in a milk plant prevents aeration of the sludge-waste mixture.

This report shows that utilizing sodium nitrate as a source of oxygen for such a purpose is not feasible. The results were obtained by several methods. The Warburg apparatus was used in one phase of the study to determine the oxygen uptake and carbon dioxide evolved. In another part of the experiment, simple jars containing sludge and skim milk were aerated with carbon dioxide-free air or nitrogen for a number of hours (5). The carbon dioxide liberated was measured. It was also determined in mixtures of sludge and skim milk containing sodium nitrate that had been left undisturbed for several days.

Earlier studies on simulated dairy waste showed that skim milk or its constituents (lactose and casein) are readily available to microorganisms in aerated sludge (1). An organic solids balance established on the influent and effluent during a continuous aeration study demonstrated that about 50 per cent of the organic matter was oxidized and the growth of the cells assimilated the remainder (3). Manometric methods using the Warburg technique were applied to determine the rate and amount of oxidation (1). These experiments demonstrated that skim milk and its two principal components had a high rate of oxidation for a few hours, but the rate was reduced to that of the control in 6 hr. At this time, 32 to 40 per cent of the substrate was oxidized. Later the application of polarographic procedures for measuring oxygen in solution showed oxygen disappearance was rapid under anaerobic conditions (2). Only a few minutes were required for oxygen depletion when 1,000 p.p.m. skim milk were added to a pre-aerated sludge. When the waste (skim milk) was less concentrated, a longer time was required to deplete the oxygen of the sludge solution. The data indicated that the rate of oxidation remained fairly constant until the concentration of oxygen in solution was less than 0.5 p.p.m.

Procedures

It had already been shown that an aerated sludge system containing skim milk, lactose, or casein had a respiratory quotient of unity (1). This indicated that the volume of CO_2 evolved was equal to the volume of oxygen consumed; that is, R.Q. = CO_2/O_2. Thus, measuring the CO_2 evolved from a system gave a measure of the oxidation

* Part II of this series appeared in This Journal, **22**, 7, 888 (July, 1950).

of the added material. The amounts of CO_2 formed in the experiments in the study reported here were determined manometrically and titrimetrically on the same sludge-substrate mixtures.

Direct Manometric Determination of CO_2

Three milliliters of aerated sludge were placed in a Warburg vessel. Into the center well was introduced 0.3 ml. 3*N* H_2SO_4 and 0.3 ml. 10 per cent KOH was put in the side arm. Substrate in the amount of 0.3 ml. was added to the sludge, and the vessel was attached to the manometer. After equilibration at 30° C. for 15 min., all vessel outlets were closed. The contents of one set of flasks were immediately mixed thoroughly, and the reading was recorded. A second set of flasks was permitted to oscillate until sufficient oxygen was used by the sludge. The contents were mixed as before. The difference in reading from that at the start gave the amount of CO_2 evolved.

Vessels were also equilibrated with nitrogen gas. Results were summarized as μl. CO_2 evolved per 3 ml. of sludge for the period of time indicated in each experiment.

Indirect Manometric Estimation of CO_2

Since the R.Q. of the substrates under study was equal to unity, the CO_2 produced and retained by the KOH in the vessels was equal in volume to the oxygen consumed. The oxygen uptake was determined as described in "Standard Methods" (8). As before, 3 ml. of sludge were placed in a Warburg vessel. The 0.3 ml. of substrate was kept separate by adding it in the side arm; 0.3 ml. of 10 per cent KOH was the absorbent in the center well.

After equilibration with air, the outlets were closed, and the skim milk and sludge were mixed. The oxygen uptake was determined over a period of 6 hr. The equivalent weights of CO_2 produced hourly were calculated by use of the appropriate factor; that is, 1 g. O_2 = 1.375 g. CO_2.

Titrimetric Determination of CO_2

The preceding determinations required small quantities of materials and special technics applicable to the Warburg apparatus. Such difficulties may be obviated for plant application by use of larger quantities and simple titrations (5). Five hundred ml. of sludge were placed in the jar and pre-aerated for a time equal to the equilibration period used in the Warburg study. Fifty ml. of the substrate were then added through the separatory funnel, and the CO_2 was collected. CO_2-free air was passed through the sludge-substrate mixture. The spent air was then bubbled through 0.1 *N* $Ba(OH)_2$, which trapped the CO_2; the excess $Ba(OH)_2$ was titrated with 0.1 *N* oxalic acid. The difference between the amount of $Ba(OH)_2$ present at the start and that found by oxalic acid titration was the amount combined with the CO_2; 1 ml. of 0.1 *N* $Ba(OH)_2$ = 2.2 mg. of CO_2. These experiments were conducted for a period of 6 hr. and a determination was made every hour.

In all experiments except one, in which the rate of air was varied, the rate of air flow was 500 ml. per minute; that is, 1 volume of air per volume of solution per minute. Nitrogen gas was also used at the same rate of flow.

Chemical Oxygen Consumed

The chemical oxygen consumed values of the total sludge, the supernatant liquor, and the substrates were determined by the rapid method (6).

Source of Sludge

The mixed sludge culture was obtained from a modified aerobic fermentor after several weeks' propagation (3). During this time, a 0.1 per

TABLE I.—Substrate Composition, Oxygen Requirement, and $NaNO_3$ Supplementation

Substrate		Oxygen Demand		$NaNO_3$ Added (p.p.m.)	Oxygen Available (p.p.m.)
Type	(p.p.m.)	Theor. (p.p.m.)	Observed (p.p.m.)		
Skim milk	10,000	11,430	3,570	10,130	5,720
Lactose	5,000	5,300	1,960	4,690	2,650
Casein	3,500	4,790	1,910	4,250	2,400

cent solution of dry skim milk was added continually at the rate of 1 l. per hour to the 20 l. in the fermentor.

Substrate Mixtures

In these CO_2 evolution studies, one part of the concentrated substrate (Table I) was added to 10 parts of sludge. Thus, 0.3 ml. was added to the 3 ml. in the Warburg vessels and 50 ml. to the 500 ml. of sludge in the aeration jars. The resulting mixtures gave the desired concentration of organic matter, as measured by the oxygen consumed.

Addition of Sodium Nitrate

The amount of $NaNO_3$ required to supply oxygen was calculated from earlier data showing oxygen utilization by various nutrients (1). Fifty per cent of the theoretical quantity required for complete oxidation was added. This was in excess of the requirement for the observed oxidation of each substrate (Table I). It was assumed that all the oxygen in the nitrate was available. Solutions of skim milk, lactose, and casein were prepared with and without the calculated amount of $NaNO_3$. Thus, the same material was used for each series of tests.

Experimental

Oxidation of Skim Milk

Table II shows results of direct manometric determinations of CO_2 in 3-ml. sludge samples to which 0.3 ml. of milk solution had been added. This Warburg test was terminated in 2.5 hr., for by this time sufficient CO_2 was produced. The importance of an oxygen supply was clearly indicated, as only about one-fifth as much CO_2 was evolved under nitrogen gas. Addition of $NaNO_3$ did not increase CO_2 production in this period of time.

Figure 1 shows the weight of CO_2 produced during a 6-hr. period when CO_2-free air and nitrogen were passed through the aerators, each containing 500 ml. sludge and 50 ml. milk solution. Simultaneously, an oxygen consumption test was made with the Warburg apparatus. The weight of CO_2 was calculated, and the values obtained by the two methods were practically identical. Addition of $NaNO_3$ had no marked influence upon the oxidation of skim milk. The amount of CO_2 evolved was only slightly greater than that ob-

TABLE II.—Carbon Dioxide Evolved from 3 Ml. of Sludge and 0.3 Ml. of Substrate

Substrate	Time (hr.)	CO_2 Evolved in Presence of			
		Air (μl.)	Air + $NaNO_3$ (μl.)	N_2 (μl.)	N_2 + $NaNO_3$ (μl.)
Skim milk, 1.0%	2.5	335	334	59	68
Lactose, 0.5%	4	368	361	142	135
Casein, 0.35%	6	309	279	13	4

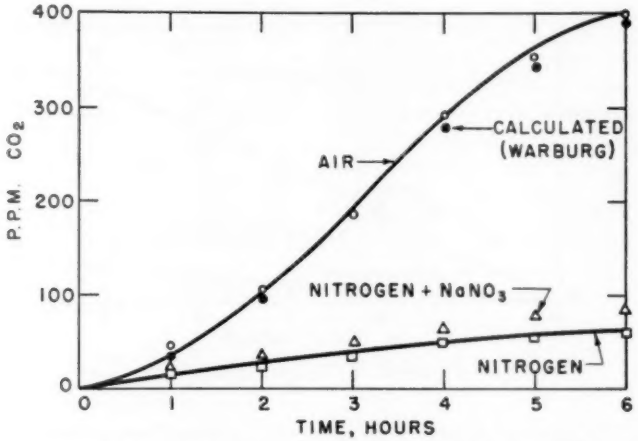

FIGURE 1.—Evolution of CO_2 from sludge-skim milk mixture.

tained when nitrogen gas alone was used, although as much as 4,000 p.p.m. $NaNO_3$ were added in some tests. Earlier tests showed that $NaNO_3$ in the presence of air had no effect.

At the termination of this experiment, the chemical oxygen consumed determinations of the contents of each flask were made and compared with the values originally present (Table III). After 6-hr. aeration, practically all solubles were gone; about 33 per cent was completely oxidized, and the remainder was in solid form. The mixtures through which nitrogen gas bubbled showed considerably less activity. Although there was some formation of solids, about two-thirds of the soluble portion still remained. The pH at the end was 7.0 in the aerated solution, 5.1 in nitrogen gas, and 5.3 in the solution having $NaNO_3$. It was obvious that the oxygen of $NaNO_3$ was unable to replace the oxygen of the air in sludge-skim milk mixtures.

Oxidation of Lactose

Similar experiments were conducted with a buffered solution containing 0.5 per cent lactose. This concentration gave the desired amount of lactose in the mixture, since one-half the solids of the simulated dairy waste consisted of this sugar. Other tests conducted with unbuffered solutions gave almost identical results.

After 4 hr., sufficient CO_2 was formed in the Warburg vessel to give the data shown in Table II. The activity in the presence of nitrogen gas was only two-fifths of that in air. Addition of $NaNO_3$ did not increase CO_2 production; hence, nitrate-oxygen was not used for this purpose in this period of time.

The quantities of CO_2 evolved in 6 hr. by 500 ml. of sludge containing lactose are plotted in Figure 2. At the same time, oxygen uptake was de-

TABLE III.—Chemical Oxygen Consumption of Sludge-Skim Milk Mixtures in Presence of Air, Nitrogen, and $NaNO_3$

Environment	Total (p.p.m.)	Solubles (p.p.m.)	Solids (p.p.m.)	Oxidized (p.p.m.)
—[1]	1,336	996[2]	340	0
Air[3]	1,001	62	939	335
N_2[3]	1,237	602	635	99
N_2+$NaNO_3$[3]	1,237	684	553	99

[1] Original substrate.
[2] Sludge solubles 38 p.p.m., milk 958 p.p.m.
[3] After 6 hr. of treatment.

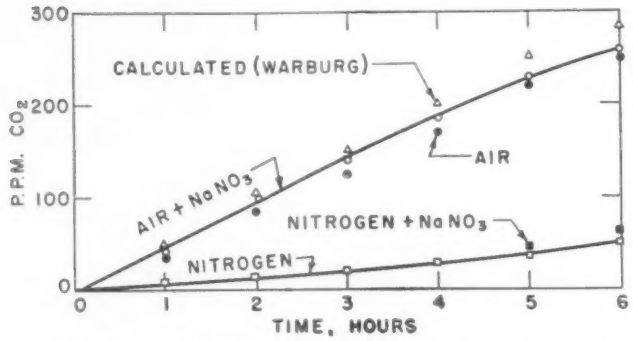

FIGURE 2.—Evolution of CO_2 from sludge-lactose mixture.

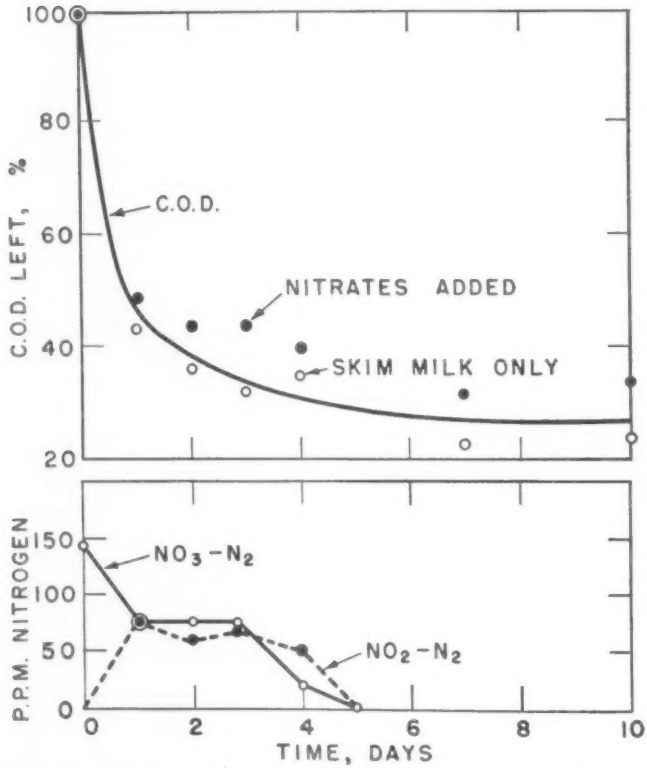

FIGURE 3.—Changes in chemical oxygen consumed, nitrates, and nitrites in the supernatant layer of a quiescent sludge-skim milk mixture.

TABLE IV.—Chemical Oxygen Consumption of Sludge-Lactose Mixtures in Presence of Air, Nitrogen, and $NaNO_3$

Environment	Total (p.p.m.)	Solubles (p.p.m.)	Solids (p.p.m.)	Oxidized (p.p.m.)
—[1]	899	581[2]	318	0
Air[3]	690	116	574	209
Air+$NaNO_3$[3]	650	116	534	249
N_2[3]	806	505	318	93
N_2+$NaNO_3$[3]	796	504	318	103

[1] Original substrate.
[2] Sludge solubles 70 p.p.m., lactose 511 p.p.m.
[3] After 6 hr. of treatment.

termined manometrically. The CO_2 obtained from the aerated mixture was slightly less than the amount calculated from the oxygen uptake in the Warburg vessel. However, the slope of the lines shows that the rate of oxidation was practically alike. Activity was retarded under nitrogen gas to about one-seventh of that in the presence of air. Addition of nitrates did not increase activity.

The analytical data in Table IV show the failure of $NaNO_3$ as an oxidizing agent in this experiment. This salt did not aid formation of solids or gas from lactose.

Oxidation of Casein

The solids in simulated dairy waste contained about 35 per cent protein. Therefore, a series of experiments was conducted with a casein substrate. In the absence of air practically no CO_2 was liberated, and addition of $NaNO_3$ did not help (Table II). Liberation of CO_2 was much slower than with the previous two substrates, requiring 6 hr. to obtain substantial differences.

In tests using casein, a difficulty occurred repeatedly. The oxygen uptake in the Warburg vessel showed that about twice as much CO_2 was produced as was obtained from the jar aerator. Apparently, the alkaline condition brought about by the oxidation of the casein held CO_2 in solution, and it was not passed into the $Ba(OH)_2$. This difficulty was overcome in experiments, in which H_2SO_4 to about pH 3 was added to the sludge-casein mixture at the end of the aeration period (5). Aeration was continued for 30 min., a fresh set of tubes being used with $Ba(OH)_2$. The amount of CO_2 evolved after acidification was about equal to the amount evolved during the experiment. Apparently, application of this test to proteins would require liberation of the CO_2 by acidification after the aeration period.

Decreasing Air Flow

The quantity of air used in these studies was in great excess in order to assure good agitation, thorough aeration, and an excess of oxygen. A study with decreasing rates of air flow was made in which the jar aerators containing 500 ml. sludge and skim milk were used. Four rates were tested—1, ½, ¼, and ⅛ volume of air per volume of sludge mixture per minute. Production of CO_2 was almost the same at these four flow rates; the total amount of CO_2 ranged from 335 to 320 p.p.m., with decreasing air flow after 6-hr. aeration.

$NaNO_3$ under Quiescent Conditions

Agitation of the mixtures in the foregoing tests may have resulted in adverse utilization of the nitrate oxygen. Further, as interest centered on the immediate effect, sufficient time was not allowed for possible use. Therefore, sludge-milk mixtures in two bottles having water traps were left undisturbed for 10 days. Each bottle had 3 l. aerated sludge and 1 l. solution containing 0.1 per cent dried skim milk. To one was added 3 g. $NaNO_3$, giving a concentration of 125 p.p.m. nitrogen, or 430 p.p.m. oxygen. At 24-hr. intervals, samples of supernatant solution were cautiously withdrawn with a pipette held 1 in. below the surface. Nitrates, nitrites, and oxygen

consumed * were determined (Figure 3).

In 24 hr., the oxygen consumed value of the supernatant was half that of the complete mixture at the start. A 2-hr. sample had shown only 10 per cent reduction. At these periods, the $NaNO_3$ had a possible adverse effect on the oxidation of the organic matter. After 7 or 10 days, there was a slight favorable action. About one-half the nitrate was changed to nitrite within 24 hr.; both were gone in 5 days. Although the nitrate was used, CO_2 or other gases did not bubble through the water trap. Addition of the $NaNO_3$ was of no help in controlling disagreeable odors.

Discussion

These experiments showed that $NaNO_3$ has no value as an oxidizing agent in the disposal of dairy wastes, especially for emergency purposes when oxidizing agents must be added to avoid odors. An oxidizing agent must have an immediate effect, because addition of dairy waste to a sludge causes anaerobic conditions in a few minutes. The rate of CO_2 produced by a sludge-skim milk mixture in 6 hr. remained unchanged by the addition of $NaNO_3$. Similar negative results were obtained when the components of skim milk were used as substrates.

On the other hand, compressed oxygen may offer a means for maintaining aerobic conditions. Such oxygen is usually easily available and should find a use for odor abatement in case of mechanical failure. Investigations are under way on use of compressed oxygen for this purpose.

Addition of nitrates was of no value during the 10-day period. The nitrates disappeared, but the disagreeable anaerobic conditions persisted. Apparently free oxygen was not made available by the microorganism to oxidize odor-producing substances. It seemed that in the presence of large amounts of organic nitrogeneous matter sufficient nitrogen for cell activity existed and the nitrate-nitrogen was not needed; hence, oxygen was not liberated.

In high carbohydrate-containing wastes, on the other hand, the nitrogen of added nitrates may be used for bacterial synthesis. All the oxygen may not be needed for growth. In that case, the excess oxygen may be diffused in the liquid and serve as a means of oxidizing malodorous substances in the same manner as in lagoons. Unfortunately, dairy wastes cannot utilize nitrates for this purpose, as such a waste contains the nutrients in balanced proportions for microbial growth.

* In Figure 3 this value is called "chemical oxygen demand (C.O.D.)"

Summary

Oxidation of skim milk, casein, and lactose by aerated sludge was determined by measuring the CO_2 evolved titrimetrically and manometrically. Evolution of CO_2, and hence the activity of the sludge, was not markedly increased by addition of $NaNO_3$. The nitrate-oxygen was not used as an oxygen source by the sludge-waste mixture, possibly because the high organic nitrogen content of the mixture did not favor the growth of desired microorganisms.

Acknowledgment

The study reported herein was made under the Research and Marketing Act of 1946.

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RAG, ROPE, AND JUTE WASTES FROM SPECIALTY PAPER MILLS *

IV. Anaerobic Digestion

By Willem Rudolfs and N. L. Nemerow

Rutgers University, New Brunswick, N. J.

The physical and chemical characteristics of rag, rope, and jute wastes from specialty paper mills indicate that the organic constituents are amenable to bacterial decomposition. The quantity of total cook and wash water which must be included for treatment is such that chemical treatment, although producing excellent clarification, is costly and produces large sludge volumes. Moreover, chemical treatment does not materially reduce the B.O.D. (2)(3). Properly seeded organic matter decomposes readily under anaerobic environmental conditions, but the rate at which the organic compounds decompose and the optimum environmental conditions for this decomposition must be determined for each type of waste. These factors may be important criteria in selecting this type of treatment as a practical and efficient method of waste disposal. Rope cook liquor and the first hour of beater wash-water waste were combined to determine the digestion rate and optimum environmental conditions, followed by digestion of the rag and jute wastes under predetermined optimum conditions.

Various factors, including nutrient addition, pH, acclimatization, loading, and inhibitory substances produced during digestion, were investigated and procedures were worked out to alleviate or eliminate the detrimental conditions. The extended studies are condensed under various headings.

* Paper of the Journal Series, New Jersey Agricultural Experiment Station.

Nutrient Addition

Because the sanitary and chemical analyses of the rope wastes showed them to be deficient in certain nutrients (1), both nitrogen and phosphorus were added (in the form of diammonium acid phosphate) to the rope waste before neutralization of the waste. The quantity of nutrients added was such that the final ratio of B.O.D. to nitrogen and phosphorus was about 20:1.

pH

It was necessary to lower the pH value of the rope waste from 12 to 7 or 7.2 before maximum digestion took place. The pH was lowered with HCl rather than H_2SO_4 to eliminate the possibility of formation of H_2S from the reduction of the excess sulfates in the digester. On a commercial scale it might be possible to lower the pH values with CO_2 from flue gases.

Acclimatization and Loading

In most cases, when the initial loading was low enough, no period of acclimatization was necessary. This initial loading was found to be optimum at a 12-day detention period, which corresponded to a B.O.D. loading of 0.01 lb. B.O.D. per cubic foot of digester capacity per day. This loading could be increased to a practical loading of 0.02 lb. B.O.D. per cubic foot per day at 20° C., corresponding to a detention period of 6 days. For example: a rope mill with approximately 100,000 g.p.d. of rope waste and pro-

viding a 6-day detention period means a digested capacity of 600,000 gal., or 80,000 cu. ft. Two digesters each 50 ft. in diameter and 20 ft. deep could handle this volume of waste.

Temperature

Rudolfs (4) found that digestion of sewage sludge at 35° C. is about twice as fast, based on gas production, as at 20° C. However, when the rope digestion was carried out at 35° C., it was found that it was not possible to increase the loading or decrease the detention period required, indicating that there are differences between sewage sludge and rope waste.

Inhibitory Material

The organic analyses of rope waste indicated that all the organic compounds should be digestible to some extent, but that there was some doubt about the toxic nature of lignin and Na_2SO_3 present in the rope waste. Welch (5) states that in distrophic types of lakes the humic substances (similar to lignins) profoundly alter the biological processes and seem to be much more important in limiting fauna than are the nutritive materials. This statement is complemented by a report on sulfite waste liquor (6) stating that whatever toxicity the waste sulfite liquor may have is most likely to reside in its lignin component. The lignin substance removed by lime treatment showed an appreciable toxicity.

There are also evidences that Na_2SO_3 could be an inhibitory agent. An article on the chemistry of the fermentation process of glycine pro-

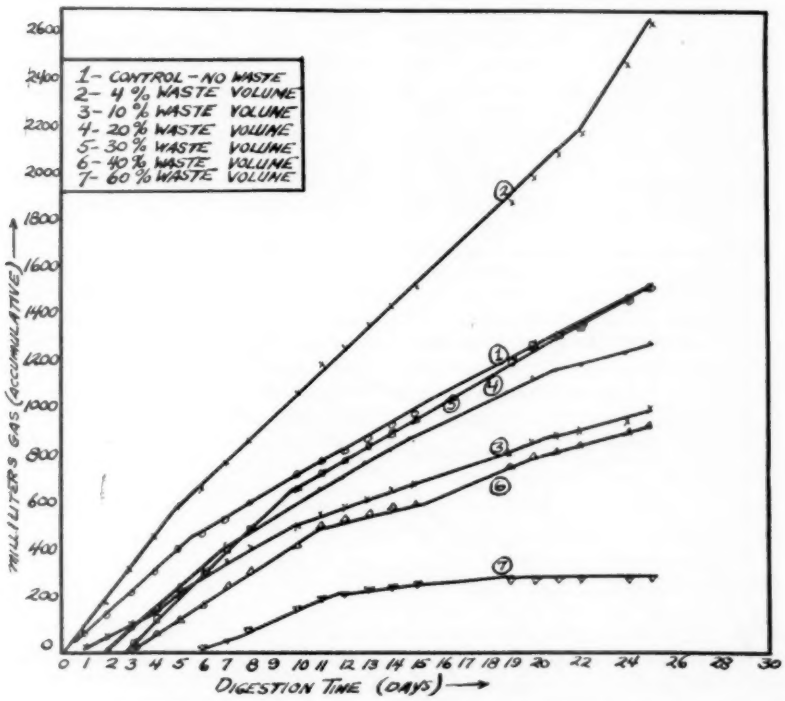
1- CONTROL - NO WASTE
2- 4 % WASTE VOLUME
3- 10 % WASTE VOLUME
4- 20 % WASTE VOLUME
5- 30 % WASTE VOLUME
6- 40 % WASTE VOLUME
7- 60 % WASTE VOLUME
MILLILITERS GAS (ACCUMULATIVE)
DIGESTION TIME (DAYS)
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 22 24 26 28 30

FIGURE 1.—Toxicity of rope waste to sewage sludge digestion.

duction (7) states that in yeast fermentation certain strains of yeast were resistant to Na_2SO_3. When yeast strains were added to solutions containing dextrose and Na_2SO_3, the alcoholic fermentations were largely inhibited, whereas glycerol fermentation was stimulated. This path of fermentation would result in less gas production and less B.O.D. reduction. This appears to be the case with rope waste digestion. Heukelekian and Lassen (8) showed that 100 p.p.m. of sulfur (as Na_2SO_3) caused a lag in gas production in the digestion of sewage solids. If the detention time is long enough it appears that the toxic effect can be overcome. Goldewagen, Manten, and Muller (9) report definite proof that methane fermentation of sodium and calcium acetates is strongly retarded by Na_2SO_3 and $CaSO_3$. At the optimum pH (6 to 6.5) 30 to 100 p.p.m. of Na_2SO_3 was sufficient to demonstrate some retardation. When the concentration was increased to 1,000 p.p.m. Na_2SO_3, complete inhibition resulted for a number of days, followed by recovery, probably because of the development of a flora capable of converting sulfites to H_2S. They also observed that at pH levels above 6.5 methane fermentation was not so sensitive to these sulfites.

In preliminary laboratory experiments (10) it was shown that rope waste addition (with no acclimatization) of more than 4 per cent by volume inhibited digestion of sewage solids (Figure 1). This indicates its nondigestibility in high concentrations, and also its toxicity.

In batch digestion experiments with rope waste containing various quantities of Na_2SO_3, the results show no lag in gas production with caustic (sulfite-free) rope waste (Figure 2), but lags of 3, 5, and 6 days, respectively, occurred with caustic sulfite wastes containing increasing quantities of Na_2SO_3. The total gas productions at the end of 20 days were very similar, showing that the rate of digestion is affected by rope wastes containing Na_2SO_3 and if the loading is low enough or the detention time long enough the digestion process is not materially hindered.

A method was devised for removal of the Na_2SO_3 from the waste before digestion. It consisted of lowering the pH to 2 with HCl and then blowing

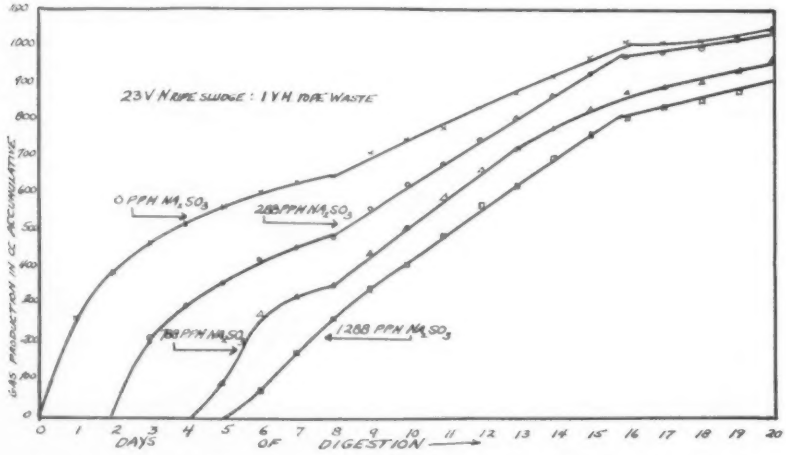
2.3 V N ROPE SLUDGE : 1 V H ROPE WASTE
0 PPM Na_2SO_3
288 PPM Na_2SO_3
588 PPM Na_2SO_3
1288 PPM Na_2SO_3
GAS PRODUCTION IN CC ACCUMULATIVE
DAYS OF DIGESTION

FIGURE 2.—Effect of Na_2SO_3 on digestion of rope cook and wash waste.

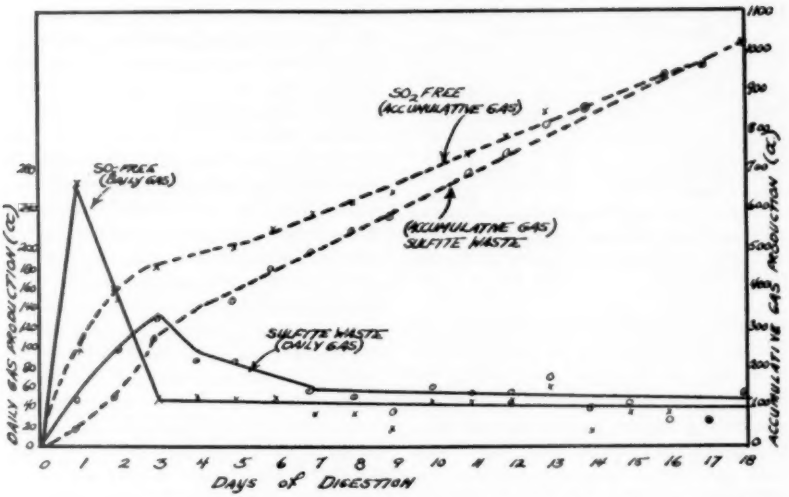

FIGURE 3.—Effect of Na_2SO_3 on digestion of neutralized and SO_2-free rope waste.

CO_2 through the waste until no reduced sulfur compounds remained in the solution. The subsequent batch digestion of the minerally fortified and neutralized waste showed that the peak of gas production was reached in one day (Figure 3), instead of 3 days, with sulfite rope waste. In continuous daily addition digestion experiments, after the removal of Na_2SO_3, it was possible to increase the B.O.D. loading to 0.04 lb. per cubic foot per day and to reduce the theoretical detention period to 4 days. This means that only one 60-ft. diameter digester, 20 ft. deep, would be needed to handle the sulfite-free rope waste.

Acid hydrolyzation of the rope waste before digestion to render complex organic compounds more readily digestible did not result in an increase in B.O.D. loading or a reduction in detention time required.

B.O.D. Reduction and Gas Production of Rope Waste at Optimum Loading Conditions

Rope waste is digestible at a loading of 0.03 to 0.04 lb. B.O.D. per cubic foot of digester capacity per day at a 4-day detention period if the Na_2SO_3 is removed from the waste prior to digestion. Without Na_2SO_3 removal, the waste is digestible at a B.O.D. loading of only 0.02 lb. B.O.D. per cubic foot per day at a 6-day detention period. B.O.D. reductions of 60 to 80 per cent and 75 to 85 per cent, respectively, were obtained by digestion at 20° C. at these maximum loadings of Na_2SO_3-free and normal Na_2SO_3 rope waste with a B.O.D. of the digester effluents ranging from 500 to 750 p.p.m., and a gas production range of 100 to 200 c.c. per gram of volatile matter added.

Digestion of Rag, Rope, and Jute Wastes Under Optimum Conditions

The maximum digestion loadings for individual mixtures of liquors and first-hour wash water of rope, rag, and jute wastes, at the optimum digestion conditions, were, respectively, 0.027, 0.036, and 0.056 lb. B.O.D. per cubic foot of digester capacity per day. The results indicate that the rates of digestion of the three wastes are not the same. For

TABLE I.—Maximum Loading Results of Rope, Rag, and Jute Wastes

Type of Waste	B.O.D. Loading (lb.)[1]	Detention (days)	B.O.D. Reduction (%)	B.O.D. in Effluent (p.p.m.)	Gas Produced (c.c.)[2]
Rope	0.027	6	83	665	129
Rag	0.036	4	77	612	218
Jute	0.056	2	72	575	182

[1] Pounds per cubic foot per day.
[2] Cubic centimeters per gram of volatile matter added.

example, the jute waste digester can be loaded with twice as much B.O.D. each day as can the rope waste digester. The fact that the jute waste contains a higher percentage of volatile acids, no Na_2SO_3, and about one-half the lignin may account for the difference in digestion rates. Moreover, although the wastes are similar in type of organic constituents, variations in digestion rates are most probably caused by abundance of one or another type of organic matter. For instance: jute waste has the lowest percentage of lignin and the highest percentage of volatile acids of the three wastes and digests most rapidly. The summarized results are given in Table I.

Jute waste is more amenable to anaerobic digestion treatment than is rag or rope waste. A storage time in the digester of only two days was needed to obtain 72 per cent B.O.D. reduction. At best, digestion at these maximum loadings would serve as a "roughing treatment," and the digester effluent requires further treatment to reduce the B.O.D.

Gehm and Behn (11) cite as the reasons for the difference in digestion rates of various industrial wastes, the character of the organic matter decomposed, the presence of extraneous substances, and the suspended solids content of the digester liquor. The sludge present in the digester carries the organisms responsible for digestion, which must make close contact with the material added. Therefore, the more seed sludge solids present in the digester, within certain limits, the greater the activity. This is an important consideration in the digestion of these alkaline cooking liquors. As the volume loading is increased with a corresponding reduction in solids concentration, the ratio of the volume of waste to seed sludge increases. In other words, the detention time in the digester at a given solids loading may become so low that subsequent reduction or even cessation of gasification results. On the other hand, if the waste volume increases without increased solids loading and the detention time is sufficient, the particles of waste come in closer contact with the seed, provided the waste is introduced in such a manner that it passes through the sludge and the rate of digestion increases. Neutralization of jute waste causes a relatively greater increase in sludge volume than of rope and rag waste. The greater volume of sludge may be contributory to better digestion of jute wastes at higher loadings than rope and rag waste. However, it is conceivable that (aside from toxic effects) neutralized cooking liquors, which are voluminous, require relatively longer digestion periods than more concentrated sewage sludges or fibrous wastes. There is no doubt, however, that the nature of the organic waste to be digested is a very important factor. For instance, the cold-water soluble solids of the jute cooking liquor contain from three to four times more volatile acids (about 40 per cent of the volatile matter) than do rope and rag wastes.

The studies have shown, in general, that with proper pretreatment the alkaline cooking liquors are amenable to anaerobic digestion. It appears, however, that digestion alone of the cooking liquors in a reasonable time does not reduce the B.O.D. sufficiently to discharge the effluent under all conditions without further treatment, but

constitutes a method of reducing the B.O.D. greatly for possible preparation of secondary treatment.

Summary

Anaerobic digestion studies show that rope, rag, and jute cook liquor, when combined with the first hour of wash water, neutralized and fortified with nitrogen and phosphorus, is digestible at maximum loadings from 0.027 to 0.056 lb. B.O.D. per cubic foot of digester capacity per day, effecting from 72 to 82 per cent B.O.D. reductions. Rope waste was the least amenable to this type of treatment. It was no more amenable when digested at 35° C. than at 20° C., nor when acid hydrolyzed prior to digestion. Sodium sulfite retarded or inhibited the digestion of rope waste. A method was devised for removing Na_2SO_3; this resulted in somewhat higher digestion loadings. Jute waste digestion required a detention period of only two days, rag waste four days, and rope waste six days. Digestion constitutes a method of treatment which may be followed by oxidation when required.

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Stream Pollution

STUDIES ON CHEMICALS WITH SELECTIVE TOXICITY TO BLUE-GREEN ALGAE

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Excessive growths or so-called "nuisance blooms" of certain blue-green algae in lakes have been recorded since early in the 19th Century (1), and with increasing eutrophication they have become a correspondingly more serious problem in lakes, streams, and reservoirs. Hence, with a view to developing possible control measures, a program of basic research on the causes of excessive growth of fresh-water plankton, particularly of bloom-producing blue-green algae, has been initiated at the University of Wisconsin.

A priori it would seem that practical elimination of blooms of blue-green algae might be achieved either on a long-term basis by the removal of some essential nutrient constituent, which would then limit their growth, or on a short-term basis by the application of highly selective toxic chemicals. Both of these alternatives are being explored.

Methods of isolation and culture of blue-green algae, as well as data on the relative requirement of different essential nutrients for optimum yields of several of the species in pure cultures, have been published (2)(3)(4). This paper presents procedures used and results obtained in the testing of a large number of chemicals for toxicity to blue-green algae, particularly of quinone derivatives. Detailed laboratory studies and preliminary field experiments with one of the most promising of these compounds, 2,3-dichloronaphthoquinone, also are reported.

Materials and Methods

Pure cultures of *Microcystis aeruginosa* and, to some extent, *Aphanizomenon flos aquae*, which are two of the most common and objectionable bloom-producing species in the Wisconsin region, have been used in screening tests. Some of the compounds most toxic to these species have been further tested on a number of other blue-green and green species, as well as on various other organisms.

The algae were grown in 125-ml. Erlenmeyer flasks with 75 ml. of a modified Chu No. 10 solution (2) under continuous fluorescent illumination and at a temperature of approximately 22° C. The composition of the nutrient solution in grams per liter was as follows: $NaNO_3$, 0.124; $K_2HPO_4 \cdot 3H_2O$, 0.013; $MgSO_4 \cdot 7H_2O$, 0.025; Na_2CO_3, 0.020; $Na_2SiO_3 \cdot 9H_2O$, 0.058; $CaCl_2 \cdot 2H_2O$, 0.036; ferric citrate, 0.003; and citric acid, 0.003. The chemicals to be tested were added 5 days after inoculation when the cultures contained 1,000,000 to 2,000,000 cells per ml. and were entering the logarithmic growth phase. At this stage, slight differences in growth rates will cause marked differences in total populations, so that the effects of the chemicals in treated cultures could be determined readily by visual comparisons with controls. However, microscopic examination of the cells to determine the extent of their disintegration after 24 hr. and the failure of treated cultures to grow in subcultures was used to determine the minimum lethal dosages.

Approximately 300 chemicals have been screened for toxicity and their effectiveness compared with that of copper sulfate, which is extensively used as an algicide in Wisconsin lakes. The chemicals were prepared in stock solutions and aliquots added to individual cultures to give the desired concentrations. In the initial tests, 10- and 20-p.p.m. concentrations were used. Compounds found to be toxic were then tested in higher dilutions until concentrations less than the minimum lethal dosages were reached.

Results

Toxicity Screening Tests

The results of tests with a variety of compounds with known or suspected toxicity to algae or other organisms, including common respiratory poisons, are summarized in Table I. As may be seen from the data, the concentration necessary to kill from 50 to 100 per cent of the cells in suspensions containing from 1,000,000 to 2,000,000 cells per ml. varies from approximately 20 p.p.m. for potassium cyanide to 1 p.p.m. for atabrine and 0.2 p.p.m. for copper sulfate.

It is of interest, also, that some of the most toxic, common weed killers used on higher plants are without appreciable effect on the blue-green algae. Several species appeared to develop normally in the presence of 250 p.p.m. of 2,4-dichlorophenoxyacetic acid. The following compounds of this type were found to be without toxic effects in concentrations up to 20 mg. per l.: indole-3-acetic acid; α-naphthaleneacetic acid; 2,3,5-trichlorophenoxyacetic acid; 2,3,4,6-tetrachlorophenol; 2,4-dinitrophenol; Na-salt of dinitro-o-cresol; potassium fluoride; and ammonium sulfamate.

TABLE I.—Effect of Various Common Toxic Substances on the Growth of *Microcystis aeruginosa*

Compound	Conc. (p.p.m.)	Kill (%)
Potassium cyanide	20	90
Methylamine·HCl	20	100
Phenylthiourea	20	50
Aniline	20	50
m-dinitrobenzene	5	50
8-hydroxyquinoline	5	100
α-naphthol	10	100
β-naphthol	20	100
Atabrine	1	100
α-benzene hexachloride	—[1]	50
Trinitrotoluene	8	100
Aquasan (colloidal Ag)	0.75	100
Copper sulfate	0.2	100

[1] 16 per cent saturated.

TABLE II.—Toxicity of Imidazoline Derivatives and Quaternary Ammonium Compounds to *Microcystis aeruginosa*

Compound	Conc. for 100% Kill (p.p.m.)
1-isopropyl-2-nonyl-4,4-dimethyl-2-imidazoline	2.0
1-isopropyl-2-(8-heptadecenyl)-4,4-dimethyl-2-imidazoline	1.0
1-isopropyl-2-undecyl-4,4-dimethyl-2-imidazoline	2.0
1-isopropyl-2-(8,11-heptadecadienyl)-4,4-dimethyl-2-imidazoline	2.0
Imidazoline from N(2-aminoisobutyl)-isopropylamine and linseed oil	2.0[1]
1-(2-ethylhexyl)-2-undecyl-1,4,5,6-tetrahydropyrimidine	2.0
3-benzyl-5,5-dimethyl-2-imidazolinethione	10.0
Cetylpyridinium bromide	2.0
Cetyltrimethylammonium bromide	2.0
2,3,5-triphenyltetrazolium chloride	2.5
2,4-dichlorobenzylnicotinium chloride	5.0
Acriflavin	1.0
Commercial quaternary ammonium salt	2.0

[1] The corresponding imidazoline or reaction product with castor oil, tung oil, neo-fat-19, or lauric, oleic, and stearic acids substituted for linseed oil in their synthesis were about equally toxic.

The results obtained with alkyl substituted imidazolines, some of which have been shown to exhibit marked toxicity to higher plants (5), are summarized in Table II. It may be seen that most of these are effective killing agents in concentrations of 1 to 2 p.p.m. Their practical use for control of algae, however, is limited, if not entirely precluded, as they were found to be extremely toxic to fish and other aquatic organisms.

Quaternary ammonium compounds also possess sufficiently high toxicity to warrant extensive testing. Representative results obtained with some of

TABLE III.—Toxicity of Quinones to *Microcystis aeruginosa*

Compound	Conc.	Kill (%)
Quinone	0.5 p.p.m.	100
Hydroquinone	0.5 p.p.m.	100
Quinhydrone	0.5 p.p.m.	100
Catechol	5.0 p.p.m.	100
3,6-dichloro-2,5-dimethoxy-benzoquinone	16% sat'd	75
Tetrachlorohydroquinone	21% sat'd	100
1,4-naphthoquinone	1% sat'd	100
2-methyl-naphthoquinone	1% sat'd	100
2-dimethylamino-3-chloro-naphthoquinone	1% sat'd	100
Quinone chlorimide	0.5 p.p.m.	100
2,3-dichloronaphthoquinone	2.0 μg./l.	100
Phenanthraquinone	80.0 μg./l.	100

these compounds also are included in Table II.

Tests of quinone derivatives soon indicated that some of these compounds are toxic to blue-green algae in much lower concentrations than any of the other compounds. Results of tests on the toxicity of quinones to *Microcystis* are summarized in Table III. The majority of these compounds are toxic in the range of concentrations from 0.5 to 1.0 p.p.m., whereas two compounds—2,3-dichloronaphthoquinone and phenanthraquinone—are lethal at concentrations of only 2 and 80 μg. per l., respectively. The results obtained with other redox compounds found to be toxic to *Microcystis* are presented in Table IV.

However, not all compounds with quinone structure and/or marked redox properties are highly toxic to blue-green algae. Thus, the following compounds were non-toxic in concentrations up to 20 mg. per l., or 21 per cent saturation in the cases of less soluble compounds: tetrachlorobenzoquinone (chloronil); tetrahydroxyquinone (disodium salt); 2,5-diphenyl-*p*-quinone; *p*-dimethyl-aminoazobenzene; 1,2-acenaphthenequinone; 1,4-anthraquinone (quinizarin) and 9 substituted anthraquinones; *o*-aminophenol-*p*-sulfonic acid; aminophenol methyl ether (*p*-anisidine); hydroquinone monomethyl ether; aminohydroquinone dimethyl ether; 2-aminoresorcinol·HCl; *m*-aminophenol; and *m*-phenylenediamine·di-HCl.

The general relationship between toxicity and chemical structure of the quinone-type compounds, as indicated by the above results, can be summarized by paraphrasing Fieser's statements (6) regarding the reactivity of the hydrogens of the compounds, as follows: (a) Any compound with two H atoms which can be oxidized from —OH or $—NH_2$ groups which are *ortho* or *para* to each other, or adjacent to one another, or which bear some similar relationship, will give rise to a fairly stable oxidant (which, in general, will exhibit toxic properties). (b) The structure of the rings and the additions to the rings merely increase or decrease the effects of the redox character (and thus the toxicity). *Ortho* and *para* directing groups, (—Cl, $—CH_3$, —OH, $—OCH_3$, $—NH_2$, $—NHCOCH_3$, $—N(CH_3)_2$, and $—CH_2$-COOH, usually weaken the bond holding the H atom to the O or N (and tend

TABLE IV.—Redox Compounds Toxic to *Microcystis aeruginosa*

Compound	Conc. (p.p.m.)	Kill (%)
o-aminophenol	2	100
p-aminophenol	1	100
p-aminophenol·HCl	1	100
p-methylaminophenol sulfate	0.5	100
2,4-diaminophenol·diHCl	2	100
Hydroquinone diacetate	1	100
Hydroxylamine·HCl	5	50
Hydroxylammonium benzoate	10	100
Hydroxylammonium chloride	2	100
Hydroxylammonium phosphate	2	100
Hydroxylammonium sulfate	2	100
Propionhydroxamic acid	10	100
2,4-dinitrophenylhydrazine	—[1]	100
p-nitrophenylhydrazine	10	100
p-nitrophenylhydrazine·HCl	1	50
Acetyl phenylhydrazine	20	100
Phenylhydrazine·HCl	10	100
p-aminodimethylaniline	2	100
p-aminodimethylaniline·HCl	2	100
p-aminodiethylaniline·HCl	1	100
Tetramethyl-*p*-phenylene-diamine·HCl	4	100
Benzidine	20	50
o-phenanthroline	0.5	100
Malachite green	5	100
Methylene blue	0.5	100
Methyl green	10	100
Crystal violet	2	100

[1] 16 per cent saturated.

to increase the toxicity). *Meta* directing groups, $—SO_3H$, $—NO_2$, —COOH, $—COOC_2H_5$, —CHO, $—C{\equiv}N$, —COR, $—NH_3^+$, and $—NR_3^+$, weaken the hydrogen bonding to O or N (and tend to decrease the toxicity). In view of this, it would appear that 2,3-dichloronaphthoquinone is probably the most toxic compound of this type which could be made without incorporating major structural changes. However, as shown by results to be presented, 2,3-dichloronaphthoquinone and phenanthraquinone must possess some additional property to account for their extreme, selective toxicity to bloom-producing blue-green algae.

Because none of the other compounds so far tested approach the toxicity of the latter compounds, further work has been limited to these two chemicals.

Lethal Dosage and Cell Number

The minimum lethal dosage of 2,3-dichloronaphthoquinone varies with the age of the cultures. To test whether this effect was due merely to the increase in cell numbers or to an increase in resistance of the cells with age of the culture, cell counts and determinations of the minimum lethal dosage were made on replicate cultures at successive 2-day intervals during a 20-day growth period. The relationship be-

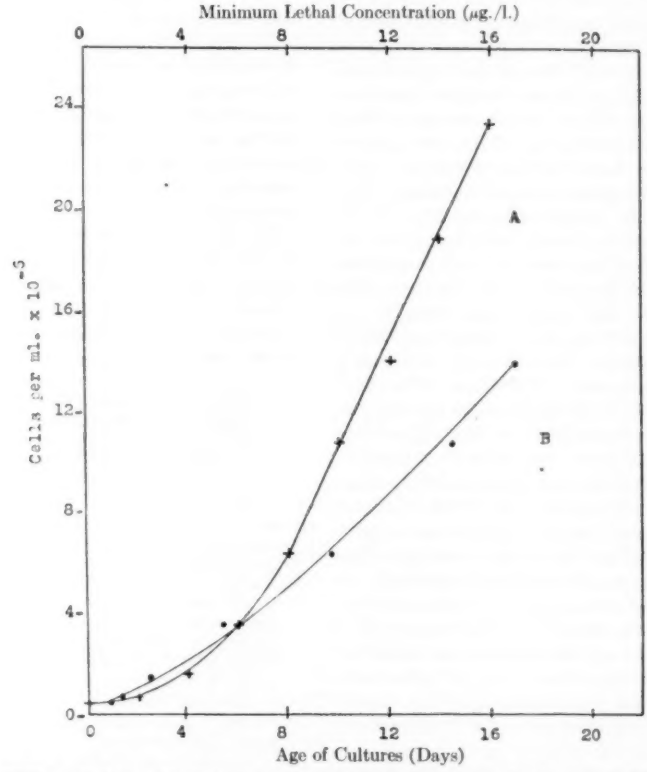

FIGURE 1.—Relationship between cell concentration and age of cultures of *Microcystis aeruginosa* (Curve A), and minimum lethal concentration of 2,3-dichloronaphthoquinone (Curve B).

tween cell numbers and age of the culture is indicated by Curve A, and the relationship between cell numbers and minimum lethal dosage by Curve B in Figure 1. The plotted values are the means of five separate experiments, all of which gave very similar results. It may be seen that over a considerable period (12 days) the minimum lethal dosage is almost proportional to the cell number, so that 1 μg. is sufficient to kill or completely prevent recurrence of growth of approximately $\frac{2}{3}$ to $\frac{3}{4}$ million cells (that is, the lethal dosage is about 5×10^6 molecules per cell).

To determine the effect of age of the cultures on the resistance of the cells to 2,3-dichloronaphthoquinone, cells were centrifuged from 6-day and 19-day old cultures and resuspended in fresh culture solution, in the 19-day old medium, after the algae had been centrifuged from it, and in the 19-day old medium to which additional nitrogen, phosphorus, and iron had been added. The minimum lethal concentration of 2,3-dichloronaphthoquinone was then determined for four different concentrations of the cells in each medium. The results from these tests showed that the cells from both 6-day and 19-day old cultures were equally sensitive to the chemical. However, cells from both the 6-day and the 19-day old cultures resuspended in the old culture medium were markedly less sensitive to 2,3-dichloronaphthoquinone than those resuspended in fresh medium. The sensitivity of cells resuspended in old medium to which nitrogen, phosphorus, and iron were added was increased over cells in unfortified old culture medium, but still required 3 to 4 times more chemical for the minimum lethal dosage than did the cells in the fresh nutrient solution. This experiment has been carried out three times with similar results in each case. Inasmuch as the cells grew more rapidly in the old medium replenished with nutrients than in the unfortified old medium, but considerably less rapidly than in fresh medium, the observed differences in sensitivity to the chemical are apparently related to variations in the growth rate of the cells.

Minimum Lethal Exposure

A series of experiments was carried out to determine the viability of *Microcystis* cells after exposure to toxic concentrations of 2,3-dichloronaphthoquinone for increasing periods of time. A toxic concentration (10 μg. per l.) was added to cultures (approximately 3,000,000 cells per ml.) and 5-ml. aliquots were removed from the treated flasks at successive intervals and cultured in fresh media. Transfers from untreated control cultures were made to determine the amount of growth to be expected in unaffected subcultures, and a second set of transfers from control cultures was made to media containing 0.5 μg. per l. of the chemical to determine the effect of the chemical carried over with the inocula into the subcultures.

The results recorded after 7 days of growth of the subcultures are summarized in Table V. The experiment was repeated three times. In all cases, the cells were killed after 10-min. exposure to the toxic solution. Identical results

TABLE V.—Relationship between Duration of Treatment and Toxicity of 2,3-Dichloronaphthoquinone to *Microcystis aeruginosa*

Culture	Effect on Culture[1]
Control, not treated	None
Treated (10 μg./l.)	100% kill
Subculture:	
0 min. after treatment	None
2 min. after treatment	None
4 min. after treatment	None
6 min. after treatment	None
8 min. after treatment	Some toxicity
10 min. after treatment	100% kill
12 min. after treatment	100% kill
24 min. after treatment	100% kill
From control, not treated	None
From control, +0.5 μg./l.	None

[1] In 7 days.

were obtained in a similar experiment in which 10 μg. per l. of the compound was added to sewage effluent. These results suggest that even though 2,3-dichloronaphthoquinone is very insoluble, it enters or is effectively adsorbed onto the cells very quickly.

Inactivation (Hydrolysis) of 2,3-dichloronaphthoquinone with Time

In alkaline solutions, 2,3-dichloronaphthoquinone hydrolyzes to 2-chloro-3-hydroxynaphthoquinone. To determine the toxicity of the latter compound, a sample was prepared by autoclaving the original compound in 0.02 *N* KOH and the toxicity of the hydrolysate was compared with that of fresh samples of 2,3-dichloronaphthoquinone added to modified Chu No. 10 solution (pH 9) either before or after autoclaving the medium. Assuming that all of the 2,3-dichloronaphthoquinone is converted to its hydrolysis product when the 0.02*N* KOH solution was autoclaved, the product, 2-chloro-3-hydroxynaphthoquinone, was at least 500 times less toxic than 2,3-dichloronaphthoquinone, but still was as active as many of the other redox compounds in Tables III and IV. Autoclaving of 2,3-dichloronaphthoquinone in Chu No. 10 solution leads to almost as great a loss in activity. On the other hand, there was hardly any loss in activity when it was added to the medium subsequent to autoclaving and left standing for 7 days.

Additional tests were made to determine whether the toxic properties of 2,3-dichloronaphthoquinone might be affected by the alkalinity or suspended matter in sewage effluent and in lake water—the latter supplemented with $NaNO_3$, K_2HPO_4, and ferric citrate to give good growth of the algae (7). The sewage effluent had a very high salt content, as well as a small amount of suspended organic material. The toxicity of 2,3-dichloronaphthoquinone to *Microcystis* was not reduced in these different media.

Relationship of Toxicity to Light

Because a previous experiment indicated that *Microcystis* cells exhibited increased resistance to 2,3-dichloronaphthoquinone when not growing rapidly in old cultures, an experiment was carried out to determine if they would be killed when treated in the dark. Cultures containing approximately 3,000,000 cells per ml. were treated with 2,3-dichloronaphthoquinone in concentrations of 2.5 to 10 μg. per l. One series of treated flasks was kept in the light and another in darkness.

At the end of 24 hr., only those cultures that had been in light were affected by the 2,3-dichloronaphthoquinone. When the cultures that had been in darkness were exposed to light for 24 hr., they also were killed. Since the cells would grow rapidly only in light, these results seem to be in agreement with those showing a decrease in sensitivity when cells were suspended in old culture media unfavorable for rapid growth. However, treated cultures which had been in darkness for 24 hr. and then were exposed to light for only 10 min. before being returned to darkness for another 24 hr. also were killed. This can hardly be explained only on the basis of a change to a rapid rate of growth, for the amount of growth induced by a 10-min. exposure to light would be rather slight. Further experiments on the relationship of light and capacity for rapid growth to the effectiveness of the 2,3-dichloro naphthoquinone now in progress may clarify the results reported.

Similar tests with quinone and acriflavin gave identical results as regards the necessity for light to obtain toxic effects; but copper sulfate, in contrast with this type of organic compound, caused disintegration of the cells as effectively in the dark as in the light.

Toxicity to Other Algae

A number of algae other than *Microcystis* were tested for susceptibility to

TABLE VI.—Toxicity of 2,3-Dichloronaphthoquinone and Phenanthraquinone to Young Cultures of Different Algal Species

Species of Algae	Survival (%) after Treatment with									
	2,3-Dichloronaphthoquinone (μg./l.)					Phenanthraquinone (μg./l.)				
	0	5	10	15	100	0	40	80	120	800
(*a*) Blue-Green Algae										
Bloom producers:										
Microcystis aeruginosa	100	0	0	0	0	100	75	5	0	0
Microcystis incerta	100	0	0	0	0	100	0	0	0	0
Anabaena circinalis	100	0	0	0	0	100	0	0	0	0
Gloeotrichia echinulata	100	0	0	0	0	100	25	0	0	0
Aphanizomenon flos aquae	100	0	0	0	0	100	0	0	0	0
Non-bloom producers:										
Anacystis marina	100	75	0	0	0	100	0	0	0	0
Coccochloris Peniocystis	100	100	100	100	—	100	—	5	0	—
Gloeocapsa membranina	100	100	75	50	0	100	100	100	50	10
Gloeocapsa dimidiata	100	100	100	100	0	100	100	100	100	10
Gloeocapsa alpicola	100	100	100	100	75	100	100	50	50	0
Lyngbya Birgei	100	100	100	100	0	100	—	—	—	—
Plectonema Nostocorum	100	100	100	100	25	100	50	50	25	10
Nostoc muscorum	100	100	100	75	0	100	100	100	100	0
Nostoc commune	100	100	100	100	10	100	100	100	100	0
Calothrix parietina	100	100	100	100	75	100	10	10	10	0
(*b*) Green Algae										
Chlorella pyrenoidosa	100	100	100	100	75	100	100	10	0	0
Scenedesmus sp.	100	100	100	100	5	—	—	—	—	—
Chlamydomonas sp.	100	100	100	50	0	—	—	—	—	—
Stigeoclonium sp.	100	100	100	100	0	—	—	—	—	—
Stichococcus sp.	100	100	100	100	50	—	—	—	—	—
(*c*) Diatoms										
(1 species)	100	100	100	100	50	—	—	—	—	—

to 2,3-dichloronaphthoquinone and to phenanthraquinone by adding a series of four concentrations of the chemicals to actively growing, unialgal cultures. The results, summarized in Table VI, clearly show that there is a striking difference between species in their sensitivity to these compounds. With the exception of *Anacystis marina*, only the organisms that produce obnoxious blooms were killed by concentrations of less than 15 μg. per l. of 2,3-dichloronaphthoquinone. Phenanthraquinone was required in somewhat higher concentrations to kill the bloom-producing species, and was less specific, as indicated by its high toxicity, for example, to *Chlorella*.

Toxicity to Other Aquatic Organisms

A series of tests was made in collaboration with K. V. Mackenthun, representing the Committee on Water Pollution of the State of Wisconsin, to determine the effect of some of the toxic chemicals (1,4-naphthoquinone, 2-methyl-naphthoquinone, 2,3-dichloronaphthoquinone, and phenanthraqui-

none) on several species of fish. These tests were carried out in a series of glass aquaria filled with 10 l. of spring water and aerated continuously. A mixed population of small fishes, 1 to 2 in. long, was put into each aquarium, about 25 per vessel, before the various concentrations of the chemicals were added. The following species of fish were used: black crappie (*Pomoxis nigro-maculatus*), common emerald shiner (*Notropis atherinoides atherinoides*), bluntnose minnow (*Hyborhynchus notatus*), rock bass (*Ambloplites rupestris rupestris*), and largemouth bass (*Huro salmoides*).

The results of these experiments, in which observations were made 24 and 48 hr. after the addition of the chemicals, showed that both 1,4-naphthoquinone and 2-methyl-naphthoquinone were toxic in concentrations of 0.3 to 0.6 mg. per l., or in about the same concentrations required to completely kill blue-green algae. Phenanthroquinone and 2,3-dichloronaphthoquinone, on the other hand, were entirely without visible effects on the fish in the 2-day period of treatment, even with excess solid dispersed in the water. On the basis of these tests, therefore, it seems that the latter chemicals may be safely added to natural waters, at least for short periods and in the very much lower concentrations required to kill the blue-green algae, without danger of toxic action on fish.

Additional observations on higher aquatic plants and green algae growing in water treated with 2,3-dichloronaphthoquinone have indicated that the chemical does not affect them. For example, species of *Ceratophyllum*, *Myrophyllum*, *Elodea*, and various filamentous and unicellular green algae have been grown in battery jars containing 10 l. of lake water (fortified with $NaNO_3$, K_2HPO_4, and iron citrate) with 2,3-dichloronaphthoquinone concentrations in excess of the saturation level (100 μg. per l.) without showing apparent symptoms of injury or retardation of growth. Snails, species of *Daphnia*, rotifers, etc., present in these solutions also appeared to be unaffected by the chemical.

Similarly, *Elodea canadensis* and a species of *Rhizoclonium* grown in 200-l. tanks in the greenhouse were apparently unaffected by saturation of the water with 2,3-dichloronaphthoquinone.

One objection to the use of copper sulfate is the possible toxic action of resolubilized copper from the lake muds on the small organisms living in the bottom of the lakes. Therefore, bottom mud organisms, mainly *Chironomid* larvae from Lake Mendota, were placed in saturated solutions of 2,3-dichloronaphthoquinone in a cold room at 10° C. No effect due to the chemical on any of the organisms could be detected after 48 hr. It is evident, however, that much more extensive tests are required to establish whether these compounds can be added continuously over a long period of time to natural waters without ill effects on fish and other fauna.

Field Trials

In view of the foregoing favorable laboratory preliminary results, field experiments have been undertaken to determine the effectiveness of 2,3-dichloronaphthoquinone in killing bloom-producing algae in the lakes surrounding Madison, Wis. This work is as yet far from completion, but the limited tests on the addition of 2,3-dichloronaphthoquinone to barrels, tanks, and lagoons containing heavy growths (130 mg. dry wt. per l.) of blue-green algae, principally *Aphanizomenon flos aquae*, in lake water or sewage effluent indicate that this chemical will effectively kill the bloom-producing algae in natural waters.

Summary and Conclusions

With *Microcystis aeruginosa* as a test organism, approximately 300 organic compounds have been screened

for toxicity to bloom-producing blue-green algae. Whereas many compounds are toxic to the algae in concentrations from 10 to 1 p.p.m., several compounds of quinone-type structure are toxic in concentrations of less than 1 p.p.m.; one of these, 2,3-dichloronaphthoquinone, is lethal in concentrations as low as 2 μg. per l. under the conditions of these tests. This compound, known to be an effective fungicide, seems to be selectively toxic to the bloom-producing blue-green algae and is nontoxic to most green algae and higher aquatic plants. In short-term tests, it had no toxic effect on fish and other aquatic organisms, even when the chemical was supplied in excess of the saturation level (100 μg. per l.) However, more detailed studies must be carried out in order to be certain 2,3-dichloronaphthoquinone is without injurious effect on fish and other organisms during long periods of exposure to the chemical.

Limited field tests in barrels, tanks, and lagoons containing heavy growths of algae in lake water or sewage effluent indicate that low concentrations of the compound (from 10 to 100 μg. per l.) are effective in selectively killing the bloom-producing blue-green algae, even when they are present in exceedingly large quantities.

However, much additional information is required on methods of application, dosage, and frequency of treatment, before definite conclusions can be reached as to whether the practical use of 2,3-dichloronaphthoquinone would represent an improvement over treatment with copper sulfate from the standpoints of cost and effectiveness.

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REDUCTION AND OXIDATION OF NITROGEN COMPOUNDS IN POLLUTED STREAMS

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In an early paper (1) reviewing the literature on denitrification, it was concluded that experimental evidence at that time failed to prove the production of N_2 in the sewage treatment process, although such a reaction was naturally possible. A recent study (unpublished) of the mixed flora of anaerobic methane fermentation cultures, selectively cultivated for a year or more, revealed the presence of such a large number of denitrifiers that a reinvestigation of the subject of N_2 formation was undertaken.

If denitrifiers could persist over long periods under strictly anaerobic conditions, it appeared that if nitrates were introduced into an anaerobic methane fermentation, reduction to N_2 might occur. Conclusive results on such a reaction would be useful in calculating the amount of nitrate required in preventing odors from lagooned cannery wastes, and in explaining the source of nitrogen gas from decomposing settled solids in post-filtration settling tanks (2).

Denitrification Study

The general plan of the denitrification experiment was to carry on an anaerobic methane fermentation of acetic acid in the presence of nitrates. The effect of nitrate addition could then be evaluated by the quantitative and qualitative analysis of the gases produced.

A specially designed fermentor previously reported by the authors (3) was used. This apparatus permitted the maintenance of a completely anaerobic fermentation, access to the fermentation liquors for feeding and analyses, and collection of all the gases produced.

The medium used had the following composition (4):

Solution I	
Calcium acetate	10.00 g.
NH_4Cl	1.00 g.
K_2HPO_4	0.40 g.
$MgCl_2 \cdot 6H_2O$	0.10 g.
Tap water	1,000.00 c.c.

Solution II	
$Na_2S \cdot 9H_2O$	1.00 g.
Na_2CO_3	5.00 g.
Distilled water	100 c.c.

To remove O_2 and add CO_2, add 3 c.c. of solution II (sterilized separately) per 100 c.c. of solution I medium after the medium has been sterilized. Adjust to pH 6.8 with sterile 1 *N* HCl.

For the addition of nitrate during the fermentation KNO_3 was first used, but the accumulation of soluble $KHCO_3$ resulted in too high an alkalinity. This was avoided by use of $Ca(NO_3)_2$, forming the relatively insoluble $CaCO_3$. $Sr(NO_3)_2$ has been found even more effective (5)(6)(7).

The inoculation was made from a stock culture originating from a municipal sludge digestion tank and maintained in the laboratory for the past two years with monthly transfers into synthetic calcium acetate media. This culture produces CH_4 and CO_2 in equal proportions when fermenting calcium acetate. Although this stock culture had been transferred under aseptic conditions for the past year, it continued to yield a variety of rod-

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form bacteria, many of which could be isolated by aerobic means. Classification of several of these aerobic organisms is described below.

Periodic gas analyses were carried out using the Burrell apparatus. Practically the entire volume of gas produced by the fermentation was analyzed. Quantitative and qualitative checks were made of methane, carbon dioxide, nitrogen, hydrogen, and oxygen.

The pH of the liquor was checked throughout the course of the fermentation using brom thymol blue indicator. It was maintained approximately at pH 7.

Qualitative analyses of the liquor for the presence of nitrate and for nitrite were carried out using the zinc reduction of nitrate to nitrite and testing for nitrite with alpha naphthylamine and sulfanilic acid (8).

To the fermentor was added 280 ml. of 1 per cent of calcium acetate media containing 280 mg. of KNO_3. Twenty grams of washed and ignited sand was used to act as a nidus for growth. The fermentation was inoculated with 20 ml. of the above-mentioned inoculum and was incubated at 37° C.

Subsequent feedings of carbon compounds and nitrates, or removal of liquid samples for analysis, were made

TABLE I.—Total Quantities of Nitrate and Acetic Acid Added to the Fermentation and Gases Produced

Time (days)	Tests for		Feedings (g.)		Gas Produced			
						Composition (%)		
	NO_2	NO_3	Acetic Acid	Calcium Nitrate	Volume (ml.)	N_2	CH_4	CO_2
0			954[1]	253[2]	—	—	—	—
20	−	−			163	16[3]	61	13
23					202	0.3	76	23
26	−	−			167	0.3	72	27
30				500	176	—	—	—
31	−	+			—	—	—	—
32			200		—	—	—	—
36					90	36	27	36
44					136	14	52	33
45	−	−	200	500	—	—	—	—
50	−	−		500	—	—	—	—
52	+				—	—	—	—
54	+				—	—	—	—
57			100		132	40	23	36
58	+				—	—	—	—
59	−	−	100	500	—	—	—	—
66	−	+			—	—	—	—
67	−	−	100		154	32	25	42
72			50		—	—	—	—
77			100	500	—	—	—	—
79					110	51	22.3	46
81	−	−	100	500	—	—	—	—
85	−	+			—	—	—	—
89	−	−	100		158	50	0.0	49
105				500	—	—	—	—
110	+	+	200		—	—	—	—
114				200	—	—	—	—
132					175	68	0.0	32

[1] As calcium acetate.
[2] As KNO_3.
[3] Adjusted for N_2 in headspace of fermentor.

by means of hypodermic needle and syringe through the vaccine bottle stopper provided. The feed solutions of acetic acid and $Ca(NO_3)_2$ were made up in the basal salt solution indicated by the formula of the synthetic culture media listed above. The foregoing operations were carried out using aseptic technique.

Anaerobic Denitrification Results

The first signs of gas production appeared 20 days after the date of inoculation. Gas production continued for 132 days, or until the date that the fluid and sand were subjected to a total nitrogen determination (Kjeldahl-Gunning procedure). During this incubation period, feedings of acetic acid and nitrates were made as shown in Table I. Variations in feeding procedure accounted for the fluctuations in the quality and quantity of gases produced. By intent, the fermentation was held in acetic acid excess for a period of time to determine its effects on the gas composition. The same was done with nitrate. These effects will be considered next.

As previously stated, a concentration of 280 mg. of KNO_3 and 2.8 g. of calcium acetate were present at the start of the fermentation, and the inoculum used for this experiment will in the absence of nitrates produce a normal methane fermentation of acetic acid with the production of equal amounts of methane and carbon dioxide. Denitrification would be expected to influence this ratio by introducing a third gas, nitrogen, and a possible increase in CO_2 due to the oxidation of carbon by NO_3. This was found to occur in the fermentation studied. A shift in gas composition occurred with an eventual total elimination of the methane fraction. The results of the periodic gas analyses are shown in Table I.

The high nitrogen content of the first gas sample analyzed (20th day), coupled with the fact that no oxidized nitrogen (NO_3, NO_2) could be detected in the fluid, showed conclusively that denitrification had taken place.

The second stage, represented by the next two gas analyses (23rd and 26th days), indicates the composition of the gas when sufficient carbon compound was present but in the absence of nitrate. The fermentation in this case was of the normal type producing the two gases, methane and carbon dioxide. The theoretical 1:1 ratio of methane to carbon dioxide is not evident, due to the solubility of carbon dioxide and to its precipitation as calcium carbonate.

The analyses on the 36th and 44th days, which were made after a feeding period, emphasized the decrease in methane gas volume which occurs after addition of nitrate. The first gas volume (36th day) was high in nitrogen and low in methane. The following analysis (44th day) shows a reversal of this situation. Here the methane concentration is higher than that of nitrogen.

The effect of high nitrate-low carbon feed on the volume of gas produced was the next step in the experimental procedure. The fermentation was maintained for a period of 4 days with nitrate but without acetate. Gas production came to a standstill until the addition of 0.1 g. of acetic acid was made, when gas production was resumed.

Further feedings of nitrates and acetic acid resulted in a complete repression of methane production and increased denitrification. Eventually, denitrification became firmly established so that only carbon dioxide and nitrogen could be recovered from the gases. Nitrate addition became essential for gasification to take place. Methane production could not be regenerated even if the fermentation was maintained in the absence of nitrate and with sufficient acetic acid. Apparently, the methane biological system is inhibited with continued exposure to

TABLE II.—Nitrogen Balance Sheet for Experimental Fermentation

Nitrogen Added			Nitrogen Recovered		
Form	Wt. of Chem. (g.)	Wt. of N_2 (g.)	Form	Wt. (g.)	(%)
KNO_3	0.28	0.039	Gas	0.559	
$Ca(NO_3)_2 \cdot H_2O$	3.70	0.570	In liquor[1]	0.062	
NH_4Cl	0.28	0.073			
Total	—	0.682	Total	0.621	91.1

[1] By Kjeldahl-Gunning procedure.

the oxidized nitrogen compound. This is in accordance with the concept that the methane organisms function only under strictest anaerobic conditions. A balance sheet showing all nitrogen fed to the fermentation is found in Table II.

The relationship between oxidized nitrogen fed and the recovery of gaseous nitrogen is shown in Table III. This comparison shows a recovery of 91.8 per cent nitrogen as gas from 0.609 g. of nitrate nitrogen. It is likely that the nitrate nitrogen unaccounted for was assimilated and synthesized into cell protein.

As shown in a previous note (9), the factor for calculating the oxygen available in $NaNO_3$ where reduction to nitrogen occurs is 0.47; where nitrogen is reduced to ammonia or to amino nitrogen, as in a protein, the factor is 0.75. Assuming 92 per cent of the nitrate reduced to nitrogen and 8 per cent to protein as previously indicated, the factor would be 0.49 as compared with the empirical value of 0.56 sometimes used.

TABLE III.—Comparison of Gaseous Nitrogen Produced to Oxidized Nitrogen Added

N_2 Added[1] (g.)	N_2 Recovered[2]	
	Wt. (g.)	(%)
0.609	0.559	91.8

[1] As NO_3.
[2] As gas.

The amount of acetic acid added to the fermentation (as the salt and free acid) was 2.204 g. The total volume of gas produced by the fermentation was 1,663 ml. at standard temperature and pressure. A considerable amount of carbonate deposition took place in the fermentation vessel. Because the volume of carbon dioxide precipitated in this manner was not estimated, a total carbon balance of the fermentation was not made.

Oxidation of Nitrogen

For a view of the reverse reaction, the oxidation of nitrogen, excerpts are quoted from reports of a study of the B.O.D. of ammonia now in progress (10) (11).

From the equation

$$NH_3 + 1\frac{1}{2}\ O_2 \rightarrow - HNO_2 \\ - 63 \text{ kg. cal.} \quad (1)$$

it appears that three atoms of oxygen are required for each atom of nitrogen oxidized to nitrite, or 3.43 parts oxygen by weight to one part nitrogen.

Bonazzi (12), using a manometric technique, reports an average value for this ratio of 2.89 ± 0.08 atoms of oxygen to 1 of nitrogen. The values range between 2.81 and 2.97, which is lower than the stoichiometric values of 3.00.

In view of the evidence that this is a biological oxidation in which the energy released is utilized for the synthesis of protoplasm, there is good reason to believe that the B.O.D. of ammonia varies from the stoichiometric value.

To approximate the amount of oxygen which might be evolved in protoplasm synthesis, Eq. 1 and

$$NH_3 + 3CO_2 + 2H_2O \rightarrow \\ CH_3CHNH_2COOH + 3O_2 + 253 \\ \text{kg. cal.} \quad (2)$$

—representing the hypothetical synthesis of the simple amino acid, alanine—were analyzed with respect to energy relationships. If it be assumed

that all of the energy generated in Eq. 1 is used in alanine synthesis, the oxidation of four NH_3 molecules would be required to supply sufficient energy for Eq. 2. This oxidation would use 6 O_2, from which can be subtracted the 3 O_2 generated in Eq. 2, leaving a net oxygen requirement for nitrification of 1.5 atoms per nitrogen atom, or a weight ratio of 1.72. Microorganisms, as a rule, are not able to utilize 100 per cent of the chemical energy available; consequently, some value between 1.5 and 3.00 for the (O/N) atomic ratio is to be expected in this case.

An extensive series of experiments is summarized in the following:

Incubation Period (days)	No. of Det.	Atomic Ratio, O/N	Av. Dev.	NH_3 Oxidized (%)
2	6[1]	3.80	±0.50	12
	5[2]	3.03	±0.04	17
	—[3]	3.45	±0.47	14
4	4	3.05	±0.04	54
5	4	2.88	±0.12	100
6	3	2.98	±0.04	100
7	3	2.93	±0.003	100
8	7	2.75	±0.03	100

[1] Highest.
[2] Lowest.
[3] Average.

The low atomic ratio of O/*N* of 2.75 is definite proof that a significant amount of oxygen is liberated in the course of nitrification.

Denitrifying Organisms

To complete the picture, a limited study of the aerobes surviving in the anaerobic culture was carried out for the purpose of determining the presence of denitrifiers.

One milliliter of the active fermentation liquor was diluted in a series of water blanks. The dilutions ranged from 1:100 to 1:1,000,000. Each of these dilutions was plated into a synthetic media essentially the same as indicated for the denitrification study except that it contained 1.5 per cent washed agar. Plates were inoculated and incubated at 37° C. until sufficient growth was obtained. This was usually 3 to 4 days. Colonies were then transferred to liquid media of the same composition.

Whether or not growth was observed in the chemically defined liquid medium, transfer was made to a sectored tryptone glucose yeast extract plate as a preliminary screening process. This was useful, for on becoming acquainted with the cultures it was possible on the basis of pigment production and morphology to identify quickly two very common Pseudomonads. Attention could then be concentrated on any colonies which appeared "new." These new colonies were included in the collection of organisms, isolated from the fermentation, and identified as to morphology and biochemical characteristics. If no growths appeared in the liquid medium or on the tryptone glucose yeast extract agar plates, it was assumed that the original transfer had been unsuccessful.

The medium utilized to demonstrate the reduction of nitrate (supplied as the potassium salt) by these organisms was of the following composition:

Beef extract	3 g.
Peptone	5 g.
KNO_3	1 g.
Distilled water	1,000 c.c.

In the case of one of the common denitrifiers found (*Pseudomonas* sp. H), a complete analysis was made of the gases produced in the peptone-KNO_3 medium under anaerobic conditions. The analyses were made with the Burrell apparatus.

Attempts to isolate bacteria from the inoculum which could carry out the reduction of nitrates were successful. By the foregoing experimental procedure several organisms were isolated and partially characterized. Complete identification was not within the scope of the work, but sufficient data were obtained concerning the physiology of

TABLE IV.—Description of Organisms Isolated from an Anaerobic Methane Fermentation[1]

Stock Culture	Sucrose	Dextrose	Lactose	Litmus Milk	Gelatin	NO_3 Reduction	Indol	Tryptone Glucose Extract	Motility	H_2S
H[2]	No gas, growth alkaline	No gas, growth acid	No gas, growth alkaline	Peptonization, rennin curd, alkaline	Liquefaction at 24 hr.	+ Gas growth	−	Yellow-green pigment	+	−
T_1[2]	No gas, growth alkaline	No gas, growth slightly acid	No gas, growth alkaline	Peptonization, rennin curd, alkaline	Liquefaction at 72 hr.	+ Gas growth	−	Large white flat colony, no pigment, undulated	+	−
T_{23}[2]	No gas, growth alkaline	No gas, growth slightly acid	No gas, growth alkaline	Peptonization, rennin curd, alkaline	Liquefaction at 24 hr.	+ Gas growth	−	Same as above, but developed pigment after few days	+	−
A[2]	No gas, growth neutral	No gas, growth neutral	No gas, growth alkaline	No change	No liquefaction at 72 hr.	+ Gas growth	−	White, slightly rugose	+	−
D	No gas, growth neutral	No gas, growth neutral	No gas, growth neutral	No change	No liquefaction at 72 hr.	− No gas	−	Granular	+	−
U_{16}	No gas, growth neutral	No gas, growth neutral	No gas, growth neutral	No change	No liquefaction at 72 hr.	− No gas	−	Raised, smooth, large, entire tannish	+	−

[1] Medium preparation procedures obtained from Ref. (8).
[2] Very active in denitrification.

these organisms so that a tentative classification could be made.

It is of significance that these organisms persisted in an anaerobic fermentation over a period of two years. The fact that they are present in large numbers (usually numerous colonies were present in aerobic plates of 1:1,000,000 dilution) indicates that the anaerobic conditions of the methane fermentation permit their growth.

The aerobes isolated and reported in this investigation fall into a definite pattern. All are Gram-negative, short, motile rods and inactive in the fermentation of sugars. Two species of *Pseudomonas* (Table IV, species H and T_{23}) and a slow-growing granular colony comprise the predominant organisms. Others, less abundant, were occasionally encountered. The descriptions of six organisms considered of importance are given in Table IV, listed in order of the frequency of their occurrence.

In order to carry out an analysis of the gas produced in nitrate broth, a special anaerobic fermentor was filled with a peptone-KNO_3 solution medium and inoculated with *Pseudomonas* (species H). Forty-eight hours after inoculation, sufficient gas had collected above the culture fluid so that an analysis could be carried out. This gas was composed of 95.7 per cent N_2 and 4.3 per cent CO_2.

In the absence of KNO_3 and under the same conditions as used in the previous experiment, no growth was observed. The oxidized nitrogen compound was essential for the facultatively anaerobic existence of this organism in pure culture, but it evidently was capable of growing in the active methane fermentation without nitrates.

Summary

The effect of addition of nitrates to a methane fermentation of acetic acid by a highly purified culture was studied. The interpretation of the experimental results is that denitrification does take place, giving rise to nitrites and nitrogen gas. A complete disappearance of methane from the gases is the ultimate result if continued feedings of nitrates and acetic acid are

carried out. In the later stages of the fermentation, gas production is diminished in the absence of either the oxidized nitrogen or the oxidizable carbon compound. Nitrogen gas is generated in the fermentation in almost quantitative amounts based on the nitrate nitrogen added. It is probable that some nitrate nitrogen goes into synthesis of cell material.

A study of facultatively anaerobic bacteria occurring in the purified culture has been made. Many of these organisms in pure culture have been shown to reduce nitrates, with the production of nitrites and nitrogen gas. All the organisms are Gram-negative, short, motile rods and inactive in the fermentation of sugars. Two of them have been tentatively identified as species of the genus *Pseudomonas*.

A factor of 0.49 is suggested for calculating the nitrate oxygen available for waste stabilization.

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THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

FROTH CONTROL IN WASTE DISPOSAL*

BY W. B. STEVENS

Socony-Vacuum Oil Co., New York, N. Y.

For some years, there has been a constantly increasing interest in the control of foam in industries. Froth (or foam †) problems occur, broadly speaking, in two categories; (a) in the process itself, and (b) in the effluent carrying away the waste products of the process. It is with the control of this latter foam, encountered in industrial wastes, and the froth which is becoming an increasing problem in certain types of sewage treatment that this paper is concerned.

Good public relations demands that industry refrain from transforming streams, rivers, and harbors into unsightly industrial gutters. Large masses of foam floating on these water surfaces serve as advertisements that industry is not doing all that it can to cut down on stream pollution. The special froth problem in many activated sludge type sewage treatment plants became so acute over the past two years that it touched off the work which is the main subject of this paper.

The control of industrial foam has been a subject of interest to the petroleum industry for a long time. The use of kerosene as a "defoamant" in many processes (such, for example, as in paper mills) harks back several generations. As time went on, the petroleum industry developed compounded oils and light products, oil emulsions and, in recent years, wax emulsions for many specific foam control problems.

It was only natural, therefore, that the Socony-Vacuum Oil Co. should have become interested in the excessive froth which has been an increasing harassment in many activated sludge sewage treatment plants. After extensive laboratory screening, followed by actual plant tests on the most promising of the laboratory products, a compounded oil containing a critically balanced proportion of organic additives was developed which shows outstanding ability to control the excessive froth in activated sludge plants and which also appears to be applicable to many industrial waste foam problems. In addition to the sewage treatment work, it is now finding successful application in at least two paper mills and a rubber reclaim plant where effluent foam had become a serious problem.

Other possible uses suggest themselves and will be investigated within the very near future, such as the effluents from antibiotics manufacturers,

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* Presented at 1952 Annual Meeting, New Jersey Sewage and Industrial Wastes Assn.; Atlantic City, N. J.; March 12–14, 1952.

† The term "froth" has purposely been adopted by THIS JOURNAL in referring to the aeration tank problem as distinguished from the "foam" problem at sludge digestion units. It is hoped thus to preclude confusion in terminology. The two words are essentially synonymous in dictionary definition, which is considered to justify this arbitrary decision with regard to their application.

textile mills, canneries and other food processers, pulp mills, etc.

The product in question, which has been known up until now as PD 709–X (but is being branded S/V Foamrex W), is a free-flowing, light-colored compounded oil having a Saybolt universal viscosity of approximately 120 sec. It has an ASTM pour point of − 20° F. and, therefore, can be easily handled as a fluid in both warm and cold weather. It is non-flammable, having a flash point of 285° F., and it weighs 7.5 lb. per gallon. Its B.O.D. is reported to be 35,000 p.p.m., which becomes negligible when it is realized that the product is recommended only to the extent of 0.5 to 1.5 p.p.m. of sewage or industrial effluent.

Application of Defoamant

Application of S/V Foamrex W presents no problem. It can be simply dripped into the liquid causing the froth at a point where there is sufficient agitation to assure that the material is reasonably well distributed through the liquid. Thus, in the first sewage plant, it was added at the beginning of pass B by means of a small pump set to deliver approximately 1 gal. of oil per hour. In a plant such as a paper mill it should be added on the suction side of the main effluent pumps to insure best possible dispersion.

The defoamant can also be applied by mixing with the water in a water spray system, if such equipment exists in a plant. Both types of application are illustrated in the data presented here.

A third method of application in an activated sludge sewage treatment plant is by pumping it into the return sludge line by means of a positive displacement pump.

Application Data

Plant Test 1

Table I is the log of a defoamant evaluation made on July 19, 1951, at an activated sludge plant of the aerated type having a capacity of 45 m.g.d. of a high-solids sewage. The aeration cycle is 6 to 8 hr. Froth conditions were described as moderate. Raw sewage entered at pass A and auxiliary raw sewage entered pass D.

As shown in Table I, flow of defoamant into the system at the head end of pass B was begun at 6:00 AM, July 19. By 11:10 AM the defoamant action was effective and all channels under test were completely free of

TABLE I.—Log of Defoamant Evaluation, July 19, 1951; Froth Conditions, Moderate to Light

Time	Rate of Defoamant Addition[1]			Sewage Flow Rate (m.g.d.)	Remarks
	(c.c./min.)	(g.p.h.)	Wt. Used (lb.)		
6:00 AM	40	0.65	—	—	Start.
9:10 AM	67	1.07	17.75	21	Good control.
10:15 AM	38	0.60	23.5	23.5	Complete defoaming in B, good control for 125 ft. in C.
11:10 AM	28	0.45	27.75	28	Complete control in B and C.
11:50 AM	—	—	—	—	Rain, shut off defoamant.
2:35 PM	—	—	—	37	Resumed test, light froth.
3:05 PM	15	—	1[2]	36.5	Visible control for 125 ft.
4:05 PM	15	—	2.5[2]	36	Stopped, B defoamed, residual effect of morning test visible in C.

[1] Defoamant added at beginning of pass B.
[2] Weight consumed from 2:35 PM.

froth, at which time the defoamant rate had been reduced to approximately 0.5 g.p.h. Rain interrupted the test for several hours and defoamant was shut off at 11:50 AM; the addition of defoamant was resumed at 2:35 PM, because froth build-up was again evident. Due to the previous rain, the volume of froth at this time was rather low and defoamant was, therefore, added at the rate of approximately 1 qt. per hour. This rate kept the froth under control and at 4:05 PM, when pass B was defoamed, the addition of defoamant was stopped. It is to be noted that the residual effect of the morning test was now visible in pass C.

Plant Test 2

A test was then carried out in a high-rate, short-cycle plant having a capacity of about 60 m.g.d. of a low-solids sewage, the cycle of aeration being 3 hr. through four passes. In this plant it was a daily occurrence to have the aeration channels inundated in froth in the morning, with froth heights reaching 10 ft. and spreading over the entire width of each pass for the length of the channel (420 ft.) Because of the exaggerated froth condition, this plant has a spray system which sprays water on the suds as a means of mechanical defoaming in channels B, C, and D of one of the tanks. Nozzles project at 5-ft. intervals from a pipe hung along the entire length of the channel above the water level on the side opposite the air diffusers. The nozzles emit a fan-shaped spray, which is directed into the sewage flow in the channel.

Table II shows the log of defoamant evaluation on July 24, 1951, at this plant where froth conditions were pronounced heavy. Defoamant was added in the first part of the test in a one-point application, as in the previous plant, at the beginning of pass B. In this case, all raw sewage enters at pass A; none enters the fourth pass (or pass D).

Defoamant was started at 9:30 AM at a rate of approximately 1 g.p.h.,

TABLE II.—Log of Defoamant Evaluation, July 24, 1951; Froth Conditions, Heavy

Time	Rate of Defoamant Addition			Sewage Flow Rate (m.g.d.)	Remarks
	(c.c./min.)	(g.p.h.)	Wt. Used (lb.)		
(*a*) Defoamant Added at North End of Pass B					
9:30 AM	—	—	—	51	Start.
9:50 AM	69	1.1	3.25	51	Very good defoamant action for 125 ft, slight effect seen for 220 ft.
9:55 AM	—	—	—	—	At end of B pass (420 ft.)
10:30 AM	65	1.03	8.25	63.5	All of B pass clear of froth and ½ of C pass; addition stopped.
(*b*) Defoamant Added in Water Spray System					
11:08 AM	—	—	—	54	Start.
11:20 AM	—	—	0.75	54	Definite control.
11:30 AM	—	—	1.50	—	Definite decrease in froth; shut off defoamant, continued water spray.
12:10 PM	—	—	—	—	Froth build-up.

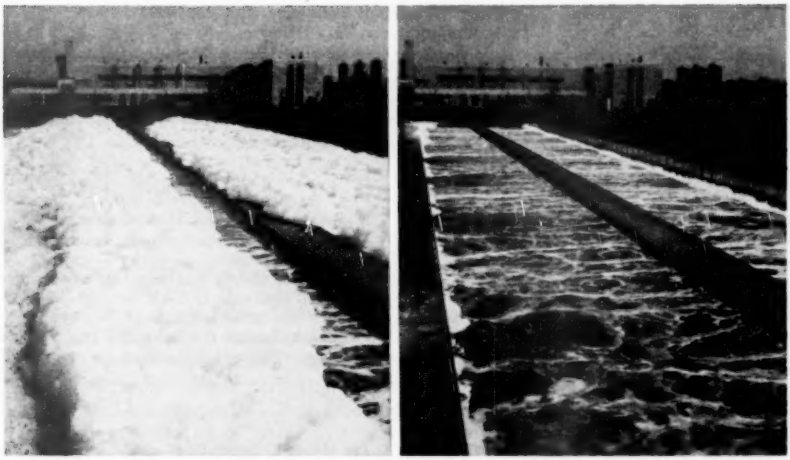

FIGURE 1.—Passes C and D of aeration tank (left) prior to start of test at 9:25 AM on July 25, 1951, and (right) at 12:25 PM on same date after addition of 0.6 p.p.m. of defoamant.

with the sewage flow rate varying through the day from 51 to 63.5 m.g.d. As shown in Table II, at the end of 1 hr. pass B was completely clear of froth and approximately one-half (200 ft.) of pass C was clear. The remainder of this pass showed definite signs of being controlled. At the end of this hour, 1.1 gal. of defoamant had been used, or, based on average flow for this unit, 0.5 p.p.m. of defoamant completely eliminated heavy froth for approximately 650 ft.

The second phase of this test, as shown in Table II, consisted of introducing the defoamant into the water line supplying the spray system. In this manner, the defoamant was introduced into the system at 240 different points throughout passes B, C, and D. This is considered a more efficient method of application and less defoamant can be employed to obtain the same defrothing effect. This part of the test gave a preliminary indication that the defoamant had greater effect in controlling the froth than water alone. After 11:30 AM, when the froth was completely on the decrease, the defoamant was shut off but the water spray was continued. By 12:10 PM froth was building up again. This led to the third test.

Plant Test 3

On the morning of July 25, 1951, froth conditions were pronounced very heavy, the suds having built up through the previous night even though the water spray system was continued throughout the night. No water was visible at pass D because of the mass of froth. Passes B and C exhibited heavier froth conditions than on the previous day. Figure 1 (left) shows the extent of the froth at passes C and D prior to the start of the defoamant test.

Table III shows that pass B was completely controlled and pass C completely controlled for one-half its length in 1 hr. The fourth, or pass D, already showed a definite decrease in froth. At this point, the defoamant was shut off and froth resumed its build-up for 1 hr. Defoamant was then resumed at 11:25 and shut off 1 hr. later, when there was complete

TABLE III.—Log of Defoamant Evaluation, July 25, 1951; Froth Conditions, Very Heavy

Time	Defoamant Consumed (lb.)[1]	Sewage Flow Rate (m.g.d.)	Remarks
9:25 AM	—	46	Start, Figure 1 (left) taken.
10:00 AM	4.75	46	B pass under control.
10:25 AM	8.0	48	B pass completely controlled; C ⅓ controlled; D def. decrease in froth, although not completely controlled. Shut off defoamant.
11:25 AM	—	45.5	Froth build-up during past hour. Started defoamant again.
11:40 AM	—	—	B pass completely controlled; C ⅔ controlled; D def. reduction in froth volume.
12:00 Noon	12.25	47	Complete control throughout.
12:25 PM	17.5	47	Complete control throughout, Figure 1 (right) taken. Stopped defoamant.

[1] Defoamant added in water spray system.

control of the froth throughout. During this hour, 1.2 gal. of defoamant had been used, which is equal to approximately 0.6 p.p.m. At 12:25, Figure 1 (right) was taken showing the complete control in passes C and D. This was 3 hr. after the start of the test, with the defoamant being applied during only 2 of the 3 hr.

Other plant-scale defoamant tests with this product have been run and at least one sewage treatment plant has been using the material regularly for the control of froth during the winter of 1951–2. Several others expect to be using it as froth conditions demand during the coming warmer months.

The question has arisen as to whether any oil could be detected in the effluent of a sewage plant using S/V Foamrex W. To answer this question, two samples were taken, one from the effluent while the defoamant was being added over a period of several days; the second, one week after the use of the defoamant had been temporarily discontinued. Analysis of the two samples showed an oil content in each of 27 p.p.m. This indicated that the oil content is probably due to the wash-off of lubricants from the various gear and chain drives and that the addition of S/V Foamrex W to a sewage treatment operation does not significantly increase the oil content of the final effluent over that present from other sources in the operation, assuming that the defoamant is used in the recommended quantities of 0.5 to 1.5 p.p.m.

Cost of Product Use

In conclusion, a brief consideration of the cost of froth control with S/V Foamrex W seems appropriate. Let it be assumed that an activated sludge sewage treatment plant of the aeration type treats 50 m.g.d. Using 0.5 p.p.m. by weight (S/V Foamrex weighs 7.5 lb. per gal.) then $\frac{8.3}{7.5} \times 0.5 = 0.55$ gal. in each m.g. of sewage. Then $0.55 \times 50 = 27.5$ g.p.d. of S/V Foamrex W, if used all day. At 14.75¢ per lb. average delivered price in 50-gal. drums, this would equal about $30 per day, if it were necessary to run for a full 24 hr. As it is probable that defoamant need only be added a relatively small fraction of the total time in the year, say 30 per cent, and because on days when froth conditions require control the defoamant would probably be added only about 1 hr. in every 2, the average cost per day would be in the neighborhood of $4.50.

THE DAILY LOG

New Britain, Conn.

By John R. Szymanski, *Superintendent*

June 20—There are times when operations just take care of themselves—in the hustle and bustle of preparing an annual report to make a few deadlines, the office door was closed to all except for emergencies. Now, however, 50 copies have been mailed out to various individuals and offices.

June 27—Fair and warmer, and all hands just oozing with energy, so the crew began work on all outside valves and valve stems. This is done each spring and has paid excellent dividends in the maintenance program. Completed the final signing of chemical contracts and filing of performance bonds with the approval of the City Counsel.

July 4—Amid the banging of fireworks around the plant property (although the sale of fireworks is illegal) Mother Nature put on one of her own bang-up shows. Torrential rain and blasting thunder kept interrupting normal operations at the plant. Nevertheless, regardless of holiday or storm, the men were all on duty for full plant operation.

July 6—Everybody is busy as a bee. The Commission held its quarterly inspection of the plant and its facilities. Everything was spick-and-span, even the innermost corners. These inspections seem to give the men's morale a big boost, especially when they all get a general pat on the back for a job being well done.

July 7—Started replacing all header air piping, with cutting and threading of pipe being done at the plant by plant personnel. We are changing from the original installation and placing the diffuser units on the outside of the longitudinal baffles instead of the inside. No immediate variation is noticed, and efficiency seems to be the same.

July 12—Working out details on the proposed contract with the town of Newington for furnishing sewer and sewage facilities. City Engineer Molleur and Chairman Stowell were consulted on the basis of payment. A plan to charge on a per unit connection is being completed, with a sliding proposition for industrial use.

July 13—The heavy grit coming into the plant after each heavy rainstorm is still a headache. It jams up all pumps and sludge lines, not to mention the heavy wear of chains on the screen and sludge collectors.

July 18—Regular stream D.O. check by State Dept. of Health. The stream remains the same as in the past; it could stand some improvement.

This seems to be salesmen's day—they all came, from brush salesman to parts salesman, and all seemed to voice one thought, "You had better order now, or else!"

July 20—The safety program seems to be very effective; it seems the entire plant personnel is danger conscious, and all precautions are being taken to prevent any unnecessary mishap.

July 27—This is mid-vacation week. All the men try to arrange their two-week vacation period as near the middle of summer as possible, and this leaves skeleton crews for full operation. With a limited number of employees this poses a problem, especially if someone should suddenly become ill.

July 28—One of the 500-c.f.m. air blowers is becoming very noisy and needs major repairs or replacement. The air units were originally furnished by The Pottstown Blower Co. It was very disheartening to learn that the company no longer exists and that replacement parts are not available.

July 29—Completed work on the Newington town contract and forwarded it

to the City Clerk for presentation and approval by the Board of Aldermen of New Britain.

July 31—Many man-hours were spent today replacing broken windows. It's odd how many are broken during the course of a year (a total of 30 17 × 12 panes were installed).

The roof was checked and touched up with a Panther Refining Co. product. This material is easy to use and does an excellent job in sealing leaks, especially around the flashing. At least now if there's any water in the plant it will not have come through the roof!

RECENT IMPROVEMENTS AT THE PLAINFIELD JOINT MEETING TREATMENT PLANT *

By Andrew Palmer

Superintendent, Plainfield (N. J.) Joint Meeting Sewage Treatment Plant

The Plainfield (N. J.) Joint Meeting sewage treatment plant serves the City of Plainfield, the Borough of North Plainfield, and the Borough of Dunellen, as well as small tributary areas of Fanwood, Watchung, and Green Brook. Approximately 60,000 persons are connected to the extensive sanitary collection system tributary to the Joint Meeting treatment plant.

History of Plant

The original treatment plant was placed in operation in 1916 and consisted of Imhoff tanks, trickling filters, resettling tanks, and sludge drying beds.

Through the years, enlargements and improvements have been made at the treatment plant, many of which were based upon experiments carried out at the plant to improve operation. Some of the improvements involved sludge removal from the Imhoff tanks, heating of sludge, and experiments in digestion. From the early experiments at the plant, the Downes (P.F.T.) floating cover was invented. Experiments were also conducted in incineration; as a result of the early studies, full-time sludge incineration was placed in operation. The series of improvements completed by 1938 provided the plant with complete secondary treatment and included a grit chamber, comminutor, primary settling tanks with mechanical sludge removal, trickling filters, final sedimentation, pre-chlorination, post-chlorination, separate sludge digestion, and incineration of sludge.

Record of Plant Growth

Prior to 1940, the average flow at the treatment plant was about 4 m.g.d., or about 80 g.p.c.d. The Plainfield area, like many areas in the state, expanded in population after World War II, with the result that the existing treatment plant became overloaded. Between 1941 and 1951 there was a constant increase in the load on the plant. The flow increased from 4 m.g.d. to the present rate of about 6 m.g.d., or an increase of 50 per cent. This increase in plant flow was accompanied by a proportionate increase in the solids and B.O.D. load on the plant.

The first units reflecting this increase in loading were the sludge digestion tanks and the incinerator. The inability of the digestion tanks to handle the excess solids resulted in an overload on the trickling filters. To complicate matters further, industrial

* Presented at 1952 Annual Meeting, New Jersey Sewage and Industrial Wastes Assn.; Atlantic City, N. J.; March 12–14, 1952.

wastes with equivalent population of from 15,000 to 20,000 persons imposed additional load on the plant. As a matter of fact, for many weeks at a time the load on the plant, including both suspended solids and B.O.D., was found to be equivalent to a population of 100,000 persons, despite the fact that the average flow was less than 6 m.g.d. The treatment of this raw sewage was further aggravated by the fact that the sewage entering the plant was septic because of the long length of travel in the trunk sewers leading to the plant and because of septic conditions originating in some of the 11 pumping stations located in the Joint Meeting system. As a result of the overload on some of the plant units, conditions became such that plant improvements and enlargements were required in order to produce a satisfactory effluent. Because of the fact that the Joint Meeting effluent discharged into Green Brook, a tributary of the Raritan River affording limited dilution for the effluent, the State Department of Health has set up rigorous standards for treatment of the sewage, one of which required that the 5-day B.O.D. of the effluent be not more than 40 p.p.m.

Study of Plant Requirements

To determine what steps should be taken to remedy conditions, the Joint Meeting engaged a consulting engineer to make a study of the conditions and make recommendations for enlargements and improvements to the plant.

Comprehensive studies were made of the collecting system and treatment plant, including plant performance, prior to construction. A full-time plant chemist was employed and numerous tests were performed to establish the capacity of existing treatment plant units. Studies were made of the sewage within the collecting system to determine methods of reducing septicity and to locate and control industrial wastes.

The studies indicated that the main plant units—the trickling filters and final settling tank—were capable of producing efficiencies of from 85 to 90 per cent on both B.O.D. and suspended solids removal. The primary settling tanks were capable of suspended solids reduction of from 40 to 50 per cent, despite limited settling time.

The sludge handling facilities were the most heavily taxed. Because of the heavy solids loading on the plant, the digestion tanks were unable to function properly. The volatile solids reduction was found to be very low. Because of limited digestion space (about 120,000 cu. ft.), sludge had to be withdrawn before being sufficiently digested. Sludge conditioning facilities were limited and controlled the rate of sludge withdrawal for incineration. Because of inadequate digestion facilities, a strong supernatant with abnormally high B.O.D. and suspended solids was carried over to the trickling filters and imposed a heavy loading on the secondary treatment facilities of the plant.

Plans were considered to increase the primary settling tanks by 50 per cent. This addition was made similar to existing settling tanks, wherein the original abandoned Imhoff tanks were converted to rectangular basins and similar interchangeable sludge scraper equipment was installed. This provided the units with a capacity of 10 m.g.d. at 2.5-hr. settling time.

Studies within the collecting system indicated that a few of the pumping stations were a source of septic conditions because of long detention periods. The flat grades in the sanitary sewer system also contributed to septic conditions. By rehabilitating and replacing in service about 200 flushing manholes with automatic siphons, and by readjustment of floats in the sew-

age pumping stations, the septic conditions were minimized. Every effort was made to improve the characteristics of the raw sewage reaching the plant in the realization that the treatment of fresh sewage would not impose as many difficulties on the plant as did the stale, septic sewage existing prior to the studies.

Furthermore, industrial waste surveys were made in the system and wastes with unusually high solids and B.O.D. were traced to their source. The search and discovery of many concentrated industrial wastes resulted in local "housecleaning" by many industries. A resultant decrease in many of the objectionable wastes containing oils, dyes, and the like was noted.

To further reduce the initial loading on the plant, industrial waste ordinances stringently limiting the concentration and characteristics of the wastes which could be discharged into the municipal sewer system were passed in each of the member municipalities. The ordinance was also adopted because certain wastes occasionally discharged into the system were inimical to the biological activity on the trickling filter beds and reduced plant efficiency.

The result of all of these studies—upon the characteristics of the sewage; upon the physical features of the collecting system; upon the efficiency and capabilities of all of the treatment plant components; and the resultant industrial waste ordinances—produced reduced plant loads and thereby mimimized the plant improvements required.

Plant Improvements

The plant improvements included additional primary settling tank facilities, additional sludge digestion tanks, an addition to the sludge conditioning building and appurtenances, and other minor improvements.

The digestion facilities were increased by about 35 per cent by adding two additional digestion tanks, each of about 22,000-cu. ft. capacity, to provide a total capacity of about 165,000 cu. ft. Sludge conditioning facilities were doubled and improvements were made to the incineration facilities, including the installation of a taller stack, a special fan for dust removal, and installation of fuel-oil burning facilities to replace pitch-burning as a supplement to gas for burning of dried sludge.

After the preparation of plans by the engineer and following approval of the plans by the State Department of Health, bids were taken on the proposed major plant additions. Award was made to the low bidder, but because the bid was high and far above the engineer's estimate on the settling tanks, the decision was made to award the contract but to temporarily delay construction of the primary settling tanks. The work of constructing the settling tanks was ultimately performed by the plant forces (see Figure 1).

The sludge digestion tanks were provided with floating covers. External heat exchangers were provided for heating and recirculation of sludge. Supernatant sampling and inspection were added to the existing and new digestion tanks to provide slow and controlled draw-off of supernatant (see Figures 2 and 3).

Additional sludge conditioning facilities were provided for the addition of alum for coagulation and dewatering of sludge prior to incineration.

The plant improvements were completed in 1950 and have since been in continuous service. Meanwhile, the plant personnel were organized to remove the old Imhoff tank concrete baffle walls, pour concrete, install base rails, and install mechanical equipment and piping for the primary settling tanks. This work was scheduled between routine plant duties and was successfully completed. The total cost for completing the two primary set-

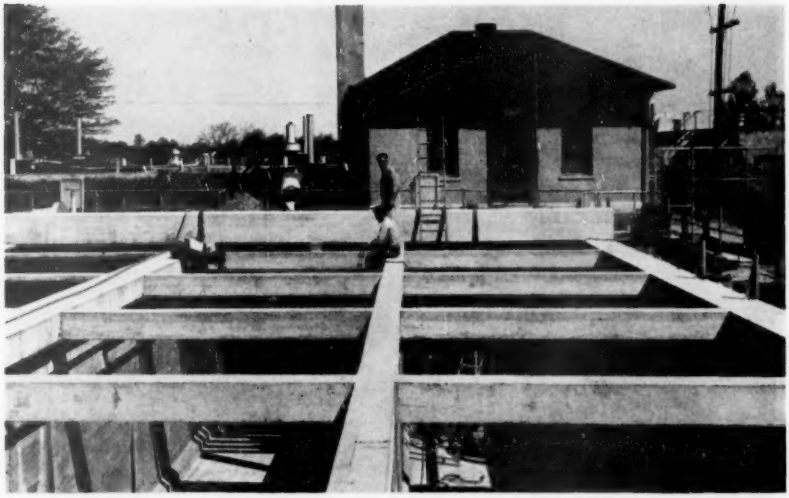

FIGURE 1.—New primary settling tanks were built by plant forces at a substantial saving over contract bid prices.

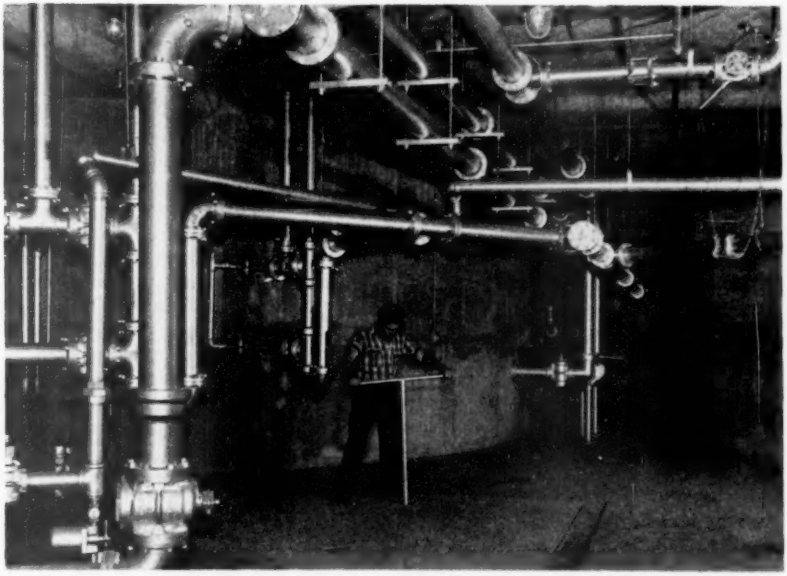

FIGURE 2.—Digester control piping in new section of operating gallery. New digesters on left, old on right.

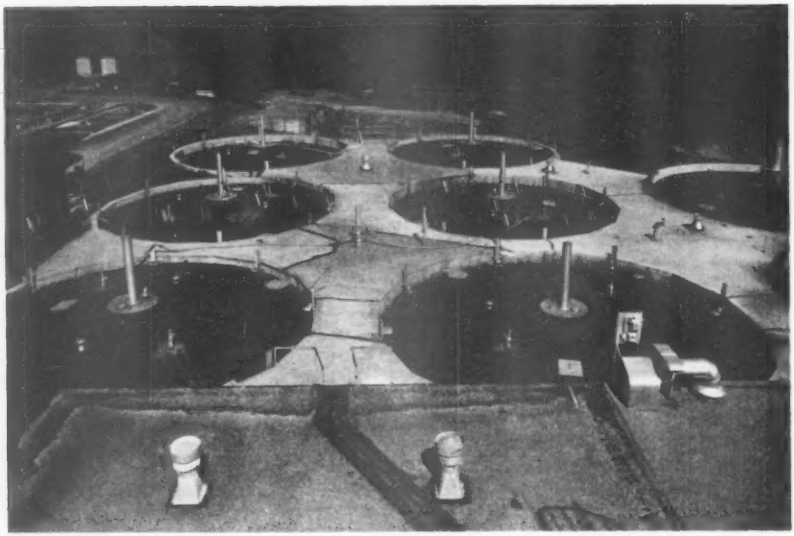

FIGURE 3.—Digesters and control galleries include six old units and two new units (extreme right) with addition to sludge conditioning facilities (right foreground).

tling tanks by plant forces was $25,556, as compared to contract bid prices of over $40,000. The construction cost of the digestion tanks, including sludge heating room, piping, valves, pumps, and appurtenances, was about $1.90 per cubic foot of digester capacity.

Results of Plant Improvements

Since the plant enlargements and improvements have been completed, the results of plant loading and plant operation have been carefully noted. It is not possible to enumerate all of the results obtained by the plant chemist, so a brief summation is presented.

Suspended solids in the raw sewage averaged 269 p.p.m., or 11,654 lb. per day in 1950, and 239 p.p.m., or 11,364 lb. per day in 1951. Based on a per capita loading of 0.15 lb., this is equivalent to a population figure of about 76,500 persons, compared to an estimated connected population of 60,000. This indicates an industrial load equivalent of about 15,000 persons. The final effluent averaged about 50 to 55 p.p.m. suspended solids, indicating an over-all removal of about 80 per cent.

The 5-day B.O.D. in the raw sewage for 1950 averaged 276 p.p.m., or 11,909 lb. per day. It was 244 p.p.m., or 11,550 lb. per day, in 1951. This is equivalent to a population of 73,000 persons based on a per capita load of 0.16 lb. daily. Between June and October, during warm weather, with optimum conditions in the trickling filter beds, the effluent B.O.D. averaged less than 20 p.p.m. The final effluent averaged 34 p.p.m. over the 2-yr. period, indicating a plant efficiency of about 88 per cent. All tests are based on composite sampling over a 24-hr. period.

Tests of the sludge in the digestion tanks indicate volatile solids of 56 per cent, compared to volatile solids of 70 to 75 per cent in the raw sludge.

Tests are performed daily by the plant chemist. Industrial waste surveys and comprehensive plant performance tests are conducted periodi-

cally to supplement the routine daily tests made.

Public Relations

The Joint Meeting plant, located outside the boundaries of the member municipalities, has made every effort to maintain and operate an efficient, clean, treatment plant. Following the completion of plant improvements, a plant inspection was held in which all mayors, councilmen, and committeemen of member and neighboring communities were invited to inspect both the existing and added facilities. Furthermore, a comprehensive descriptive and pictorial bulletin (see THIS JOURNAL, **23**, 4, 552; Apr., 1951) was published by the Operating Committee to inform the citizens of the municipalities of the work accomplished by the Joint Meeting and plant forces.

The public relations work has led to a better understanding on the part of governing bodies and citizenry of the problems encountered and work accomplished by the Joint Meeting and supervising personnel. It has paid dividends in facilitating decisions on many matters that were previously vague "necessary expenditures" in budget meetings.

INTERESTING EXTRACTS FROM OPERATION REPORTS

If you laugh at your troubles you probably always will have something to laugh at.

Annual Report of Greater Winnipeg (Can.) Sanitary District for the Year 1950 *

BY N. S. BUBBIS, *General Manager*

During the spring of 1950, the disastrous flood in the Red River and Assiniboine valleys caused the District plant to cease operations as a treatment plant and act rather as a large pumping station to dewater all areas that could be diked and later assisting in dewatering flooded areas so as to make them habitable as quickly as possible. As a result of the flood and its aftermath, the plant was not able to return to normal operations for some time. As a matter of fact, the effects were still being felt at the end of the year. Immediately following the flood, every effort was made to place the District's facilities back in service as quickly as possible. However, certain major structures were so badly damaged that extensive repairs, and in some cases replacements, had to be undertaken.

Among the damaged installations were three major river crossings and the corrugated metal section of the plant outfall sewer. The latter is being replaced with 495 ft. of reinforced alkali-resisting concrete sewer on wood pile foundations and coated with various experimental linings. These linings include ciment fondu (2-in. layer), plaster coat, water glass, bitumastic asphalt, heresite, and ciment fondu grout applied by guniting.

As a result of the flood, considerable quantities of silt and clay got into the the sewers and finally into the plant's digesters. The presence of the silt made it virtually impossible to vacuum filter the sludge and it was not until nearly the end of the year that normal operation was restored.

The District's total cost of flood fighting and flood damage is estimated to be $173,000, of which the major portion will be spent in 1951. As a

* For last previous extract see *Sewage Works Journal*, **19**, 5, 907 (Sept., 1947).

result of the flood costs and the disruption of normal operations, both during and after the flood, comparisons of 1950 operating costs with those of other years are not warranted.

Acid-Resistant Cement

Experiments with ciment fondu, an alumina cement, indicate good acid resistance. This property indicates the desirability of trying it for repair work on concrete disintegrated by sewage spray action and gases.

Sludge Lagoons and Drying Beds

In an effort to find an economical substitute for costly additional sludge facilities needed at the plant, six test lagoons and two drying beds were constructed. Three of the experimental lagoons are unusual, in that they are provided with underdrains because of the impermeability of the underlying Red River gumbo.

A summary of 1950 operating data is given in Table I.

TABLE I.—Summary of 1950 Operating Data, Greater Winnipeg Sanitary District *

Item	Average
Equivalent population, estimated	267,000
Rainfall (in.)	22.42
Sewage flow (m.g.d.)	25.8
Grit (cu. ft./m.g.)	0.75
Settleable solids:	
Plant influent (ml./l.)†	6.9
Clarifier effluent (ml./l.)	2.3
Removal (%)	66.6
Suspended solids:	
Plant influent (p.p.m.)†	330
Clarifier effluent (p.p.m.)	140
Removal (%)	56.6
B.O.D., 5-day:	
Plant influent (p.p.m.)†	230
Clarifier effluent (p.p.m.)	130
Removal (%)	44.5
Raw sludge to digesters, total (m.g.)	11.28
Dry solids (tons/day)	12.8
Solids (%)	9.0
Volatile (%)	70.7
Sludge from digesters to filters, total (m.g.)	4.68
Digested sludge:	
Solids (%)	7
Volatile (%)	52
pH	7.4
Sludge gas:	
Produced, total (mil. cu. ft.)	40.49
Used for heating, total (mil. cu. ft.)	23.89
Wasted, total (mil. cu. ft.)	16.60
Produced, daily (cu. ft.)	120,200
Wasted, daily (cu. ft.)	59,610
CO_2 (%)	32.7
O_2 (%)	0.2
CH_4 (%)	66.7
Elutriated sludge:	
Sludge handled, total (m.g.)	4.79
Dry solids, effluent (%)	0.30 to 0.91
Alkalinity (p.p.m.)	1,010 to 1,265
pH	7.0
Solids (%)	85.2 to 91.9
Volatile (%)	35.1 to 50.9
Sludge cake from plant:	
Total, wet (tons)	1,299.6
Total, dry (tons)	391.4
Ferric chloride used:	
Total (lb.)	46,395
Dose (% of solids filt.)	5.2
Days filters operated	57
Filter rate (lb. dry sol./sq. ft./hr.)	3.6 to 5.0
Cost of operation, total ($):	
Outside stations and secondary sewers	60,567.58
Flood costs	21,457.32
Treatment plant	84,174.48
Flood costs	14,223.77

* All flows and capacities in U. S. gallons. † Includes solids in elutriate and filtrate returns.

Annual Reports of Niles, Mich., Sewage Treatment Plant for Fiscal Years 1949–50 and 1950–51

By L. D. Working, *Superintendent*

The Niles sewage treatment plant and intercepting sewer system was constructed during 1948–49. Total cost of the project, including engineering fees, equipment, bond interest, and necessary contingencies, was about $700,000, of which $75,000 was taken from an existing sewer fund; $175,000

was contributed by the Board of Public Works, which operates the electric and water departments and the new sewage treatment plant; and the remaining $450,000 was financed through revenue bonds amortized over a 25-yr. period. Sewer charges were set up at the rate of 85 per cent of the water charge to provide approximately $63,000 per year to cover bond interest and principal, and plant operating and maintenance costs.

The collector sewers carry, in addition to sanitary sewage, industrial wastes and storm-water runoff from roof and street drains.

Treatment consists, briefly, of bar screening with trituration of the screenings, pumping to a mechanically-cleaned grit chamber, clarification in rectangular tanks, and chlorination with a 20-min. contact period.

Sludge digestion is accomplished in two fixed-cover, heated, concrete di-

TABLE III.—Summary of Operating Data for Niles, Mich., Sewage Treatment Plant for Fiscal Years 1949–50 and 1950–51

Item	1950 Average	1951 Average
Rainfall (in.)	54.29[1]	32.57[1]
Trib. population, est.	14,000	14,000
Sewage treated (m.g.d.)	2.47	2.3
Grit, est. (cu. ft./m.g.)	1.35	1.78
Total solids:		
Raw sewage (p.p.m.)	673	790
Effluent (p.p.m.)	561.6	629
Reduction (%)	16.7	20.0
Suspended solids:		
Raw sewage (p.p.m.)	158.9	190
Effluent (p.p.m.)	82.1	95
Reduction (%)	48.3	50.0
Settleable solids:		
Raw sewage (ml./l.)	1.98	3.70
Effluent (ml./l.)	0.53	0.56
Reduction (%)	78.5	85.0
B.O.D.:		
Raw sewage (p.p.m.)	55.4	81.0
Effluent (p.p.m.)	32.7	51.0
Reduction (%)	41.0	37.0
Raw sludge:		
Amount (g.p.d.)	4,211	3,043
Total solids (%)	6.6	6.0
Dry solids (lb.)	2,117	1,554
Vol. solids (%)	57.1	58.0
Vol. solids, dry (lb.)	1,150	893
Supernatant liquor:		
Amount (g.p.d.)	4,045	5,676
Total solids (%)	0.26	0.32
Vol. solids (%)	54.3	56.0
Digested sludge:		
To beds (gal.)	14,810[1]	278,340[1]
Total solids (%)	7.4	9.4
Total solids, dry (lb.)	9,150[1]	214,600[1]
Vol. solids (%)	48.0	45.0
Vol. solids, dry (lb.)	4,390[1]	97,020[1]
Gas production:		
Cu. ft. per day	5,026	6,491
Cu. ft. per lb. vol. solids	4.7	7.3
Cu. ft. per capita per day	0.36	0.46
Chlorine:		
Used (lb./day)	90.0	90.5
Residual in effl. (p.p.m.)	0.49	0.51

[1] Total for year.

gesters having a total capacity of 642,000 gal. Sludge is dried on underdrained sand filter beds for use as a soil conditioner. Digester gas is used in the plant for pumping and heating.

Full-scale operation began Aug. 5, 1949. By Aug. 26 a small amount of gas was being produced. No seeding or liming was necessary, as there was no foaming. Circulation of the primary tank contents has been continued to discourage scum formation from substantial quantities of petroleum oils, greases, chicken feathers, and other materials in the raw sludge and scum. Storage in the second sludge tank became so compact that pumping was impossible until the contents were heated and recirculated and fresh sludge was added. Sludge with 9 to 10 per cent solids of 45 to 47 per cent volatile content and very little odor has been drawn to the beds, where it cracks in 2 days and is dry enough to remove in 10 to 14 days.

Landscaping has been confined to grassing the immediate plant area and building up adjacent low-lying land for future development into a park.

Table III is a summary of operation data for the two years.

TIPS AND QUIPS

New Blasting Hazard

As if there weren't enough things to keep in mind regarding blasting safety procedures and use of radio transmitters, it has now come to light that the two seemingly unrelated activities can produce some highly dangerous situations. Reference is made to announcements in the May, 1952, issue of *Safety News Letter* of the Public Employee Section, National Safety Council, page 5, and the April, 1952, issue of *National Safety News*, page 30.

As a result of research the Columbus and Southern Ohio Electric Company has issued the following pertinent instruction:

KEEP RADIO AWAY FROM BLASTING CAPS!

If you do blasting, or are in the vicinity of blasting, keep radio away from blasting caps or connected control wires. Radio-frequency energy from such sources as radio broadcasting stations, two-way radios, television transmitters, radar, shoran mica-wave relays, and high-powered amateur transmitters can set off blasting caps without any physical connection with the blasting circuit.

The following rules shall be adhered to at all times by employees driving company equipment with two-way radios:

1. If electric blasting caps are within 300 ft. of any two-way radio transmitter, keep them in a tightly closed all-metal can. *Never* open the can when the transmitter is in use.
2. *Never* carry caps in a vehicle equipped with two-way radio unless the caps are in an all-metal box, composed of 24-gage iron, lined with wood.
3. Do not use a radio transmitter within 300 ft. of any electric blasting or connected control wires.
4. *Never* use a radio transmitter in or near a quarry, but notify the base station before entering a quarry.
5. *Never* use a radio transmitter while refueling a vehicle.

Incidentally, if you ever have to do any blasting it would be well to check beforehand for close location of any other radio-frequency emission apparatus, such as diathermy machines, radar, high-frequency electric furnaces, high-frequency welding power sources, etc. You may save yourself some serious trouble.

Atomic Compound Finds Popular Application

An anti-radioactivity liquid compound, "Radiacwash," widely used by atomic and nuclear scientists for removing radioactve contamination from laboratory equipment, garments, and personnel, has been discovered to have everyday use in household and industry for cleansing metals and removing rust. According to the manufacturers, it is the first popular application of a specialized compound previously used only in atomic energy laboratories and for the control of atomic bomb radioactive contamination. The product, developed by Atomlab Inc., New York City, is a new liquid soaplike compound that achieves decontamination by uniquely "sequestering" or picking up ions.

Because Radiacwash removes both radioactive and non-radioactive ions down to the minute quantities permissible in atomic laboratories, it also serves in some less spectacular household and industrial applications. It is being used for cleansing surfaces free from corrosion and oxidation products which tarnish aluminum, brass, copper, iron, and other metals. It removes tarnish from many types of metallic household utensils; in industry it is a recent substitute for corrosive cleaning acids.

Safe Barricading Procedures

At a meeting of the Michigan Chapter, American Public Works Association, C. F. Westlake, safety supervisor, Underground Line Dept., Detroit Edison Co., listed the following barricading procedures, as reported in the April, 1952, *Safety News Letter* of the National Safety Council:

1. Red lanterns should be placed 2 ft. or higher on barricades; flags, 4 ft. or higher, with 5 to 6 ft. preferred.

2. Red lanterns should be spaced 3 to 4 ft. apart transverse to the direction of traffic, 8 to 16 ft. parallel to traffic. There should be at least one flag on each barricade.

3. The distance of the first warning sign, red light, or flare in front of excavation or other construction work will vary according to the work location and traffic conditions. Several warnings and lights are suggested at distances of 15 to 350 ft.

4. The minimum protected distance on either side of an excavation or work area should be 3 ft., with more if permissible.

5. On curved streets several warning signs and lights placed around the curve may be necessary as a forewarning to traffic. Radius of curve, speed, amount of traffic, and location of job will determine the location of warning signs and the number needed.

6. The most effective barricades for protection of pedestrians and vehicles are wooden barricades, steel manhole guards, both with red flags and lanterns, and trucks with red blinker lights for manhole work.

7. Of several utility companies questioned, all but one agreed that yellow with black stripes was the most effective coloring for barricades. The exception preferred solid red.

8. On jobs along highways in suburban areas the kerosene torch is preferred, although some red lanterns are used. In populated areas the red kerosene lantern hung from a barricade is preferred.

9. For work requiring removal of a manhole cover and not consuming much time, a vehicle is parked in front of the manhole and an advance warning sign or flagman is put out.

10. To protect workmen and vehicular traffic on night trouble work, most utilities use trucks equipped with red flasher lights. Red kerosene lanterns and barricades are used if the truck does not give adequate protection. The Detroit Edison Co. uses portable battery-operated red flashers, as well as the truck flasher lights.

Mr. Westlake further explained that each situation to be dealt with will offer different conditions to be met, but application of sound safety principles and judgment will achieve an accident-free, well-planned job.

Burn Treatment

A new local treatment for burns is described by P. E. Spangler in *U. S. Armed Forces Medical Journal*, **3**, 105 (Jan., 1952). The treatment consists essentially of the application of a gel composed of partially hydrolized casein, sodium lactate, and sodium lauryl sulfate, followed by a 4-ply, coarse-meshed gauze impregnated with zinc acetate.

Twenty-two cases are described briefly. Although the author's experience was limited, he recommends the method as superior to any other local treatment, on the basis of easy and quick application, rapid relief of pain and distress, greatly reduced incidence of infection, prevention of loss of serum, use of the injured member, easy transportation, healing of first- and second-degree burns in 5 to 12 days, self-debriding of third-degree burns in 12 to 14 days, and minimum scarring.

New Methods of Utility Billing

Two cities have recently changed their procedure in handling utility bills to operations that may be of use to someone else faced with that problem. The Municipal Finance Officers Association reports that a new scheme in Pendleton, Ore., allows citizens to authorize their banks to pay water and sewer bills. There, water customers having checking accounts at local banks may sign a permit authorizing the bank to charge their checking account with the amount of the city's monthly water and sewer bill. Each month, at the time the water-sewer bills are prepared, the bills of customers authorizing payment by the bank will be deposited at the bank in the same manner as a check signed by the customer.

The banks have agreed to accept these bills from properly prequalified customers and treat them just as they would a check written by the same customer on his bank account. The water-sewer bill is returned to the customer at the time the bank mails his bank statement and cancelled checks. This procedure not only relieves customers of the responsibility of remembering to pay their bills every month, but also cuts down on the time spent by the city in mailing out bills.

Another city that is saving time and money in utility billing procedure is Boulder, Colo., where the city has made an agreement with the University of Colorado to have the city's quarterly water bills prepared by the University's statistical service department. IBM equipment and university personnel will be used at a cost of $275 a quarter. It is estimated that this plan will save the city $900 annually over present billing costs.

Brrr. . . .

According to the May, 1952, issue of Purdue University's *Sanitary Engineering News*, the city engineer of Fairbanks, Alaska, had the answer to the problem of sewer blocking when the ground froze to 10 ft. below the surface. He simply appealed to the residents to take baths every day so the warm water would keep the sewers open and flowing!

Reviews and Abstracts*

Test for Traces of Organic Matter in Water. By A. I. Medalia. *Anal. Chem.*, 23, 1318 (1951).

A new technique is presented for the determination of traces of organic matter in water. The new determination uses ferrous iron and hydrogen peroxide in the digestion step and determines the excess reagent with ceric sulfate in the presence of a ferrous iron indicator. The digestion is carried out for 15 min. at room temperature. The authors admit that the system oxidizes only a small proportion of the organic matter, or gives only a small fraction of the oxygen consumed value shown with the acid dichromate reflux method of Moore. However, there is a large blank in the acid dichromate method, which masks the detection of the true amount of organic matter at the trace level. Chlorides also interfere by their quantitative oxidation in the acid dichromate technique. This is not true of the new test. In comparison with the classical permanganate test for oxygen consumed the new test shows a better (lower) limit of detection and good reproducibility.

The high blanks with the acid dichromate procedure are caused by the poor quality of the reagent grade of sulfuric acid currently available. R. S. Ingols

Crop and Soil Reactions to Applications of Hydrofluoric Acid. By W. H. MacIntire, S. H. Winterberg, L. B. Clements, L. J. Hardin, and L. S. Jones. *Ind. Eng. Chem.*, **43**, 1800 (1951).

The recent heavy use of fluorine in atomic energy installations and many other industries underlines the need for knowledge of the effects of hydrofluoric acid derived from the atmosphere upon soil fertility and upon plant growth directly. The present studies indicate that yields, fluorine uptake, and soil acidity were not affected significantly by applications of hydrofluoric acid that were in simulation to increments that would be expected to reach the soil through rain and dew. This was in contrast to the effects induced by parallel amounts of hydrochloric acid.

R. S. Ingols

A New Colorimetric Method for Determining Oxygen Dissolved in Water Without Using Iodine Compounds. By G. Gad and A. Becker. *Gesundheitsing.*, 69 358 (1948).

In a colorimetric method for determining dissolved oxygen, manganous chloride and sodium hydroxide are first added. The precipitate of manganic hydroxide is dissolved in dilute sulfuric acid and sodium pyrophosphate. An acid manganic pyrophosphate, equivalent in amount to the dissolved oxygen and red-violet in color, is formed. The amount of oxygen present is calculated by comparison with a potassium permaganate solution of known concentration.

H. P. Orland

Proceedings of the Sixth Industrial Waste Conference. *Eng. Bull.*, 35, No. 6 (Extension Series No. 76), Purdue Univ., (Oct., 1951).

This is a continuation of abstracts published in This Journal, **24**, 6, 801 (June, 1952).

Cyanide Poisoning. By A. Vogel and Don E. Bloodgood. Pp. 329–336.

The attention of health workers has been drawn to difficulties arising from

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

accidental poisoning by cyanides used in metal plating and in fumigation.

After summarizing data on human and animal tolerances to cyanide under various conditions, the mechanism of cyanide poisoning is discussed. Cyanides poison by inhibiting tissue oxidation, which is vital for life. The inhibition is maintained only during the presence of the cyanide, its removal allows the return of normal functions, if death has not occurred. Cyanide poisoning is a form of asphyxia caused by the arrest of internal respiration.

Sodium nitrite, sodium thiosulfate, and p-aminopropiophenone therapies are discussed. Tests to find an antidote among several commercial enzymes were negative. An extensive bibliography is appended.

D. A. Okun

Legal Problems in Sanitary Engineering. By Samuel A. Greeley and Kenneth V. Hill. Pp. 337–343.

The major steps involved in the initiation and completion of a relatively large sanitary engineering project are listed and discussed. Among the major steps are the following: (a) expression of need for project, (b) feasibility of project by government, (c) suggestions for accomplishment, (d) competent engineering for preliminary investigations and recommendations, (e) preparation of a legal document for project, (f) public approval of project, (g) financing the project, (h) procurement of land and rights of way, (i) detailed preparation of plans and specifications, (j) letting of construction contracts, (k) supervision and inspection of contracts including progress payments to contractors, (l) closing of contracts upon completion of work including final payments, and (m) placing works in operation. In addition, a brief statement is given on who pays for the cost in industrial waste treatment.

Waste Saving at American Maize Products Company. By E. M. Van Patten and G. H. McIntosh. Pp. 344–362.

At an investment of about $850,000 the American Maize Products Company has been able to effect a reduction in the total bio-loading of its plant effluent from an average population equivalent to 350,000 in 1940 to 28,000 at present, for a reduction of 92 per cent. Of the present loading, a population equivalent of 20,000 discharges to the Hammond (Ind.) Sanitary District sewage treatment plant. Pending developments in the industry and plant improvements are expected to reduce the Hammond loading by at least 40 per cent. To obtain these removals the company has instituted control measures to eliminate the human factor as much as possible and thereby insure normal steady control with better than average freedom from accidental shock loads. This reduction in trade wastes has been accomplished by the elimination and saving of solid materials normally considered waste and not by elaborate pretreatment by sanitary disposal techniques. Direct benefits were incurred from this program in that the company now experiences a 1 per cent increase in over-all plant yields over what was once thought normal, or at the present cost of corn, roughly worth $175,000 per year.

Conrad P. Straub

Composting Paunch Manure. By V. R. Rupp. Pp. 363–366.

Accepting a premise, established by a school of gardening, that decomposed organic matter is much superior to inorganic fertilizers for restoring fertility to the soil, the writer points to the characteristics of paunch manure and pen manure which make these readily suited for compost preparation; describes a method that has proven successful in composting these materials; and concludes that this means of disposal of two unwanted waste products of the meat packing industry is not only satisfactory but can produce, in limited local markets, a useful material which can be sold at a price to cover costs of production, and perhaps at a small profit. Winter temperatures, adverse to the digestion of organic matter, and higher labor costs during cold weather months offer obstacles to the complete obligation of all paunch manure in this manner. These may be overcome by providing some form of shelter for compost piles.

Bruce M. McDill

Application of a Rapid Chemical Oxygen Demand Test for Determining Organic Pollutions. By Janet B. Pepinsky, Nandor Porges, and Sam R. Hoover. Pp. 367–374.

The paper reports on a study of the accuracy of a dichromate chemical oxygen consumed test for determining organic

pollution and its sensitivity to variations in experimental procedure.

The procedure is specified in detail. Tests on 1,000-p.p.m. solutions of water-soluble organic compounds gave greatly varying degrees of oxidation, ranging from less than 40 per cent for glycine to 100 per cent for cellulose. Results are tabulated. Variation in time of heating with dichromate from 6 to 9 min. increased the per cent oxidation of glycine from 38 to 86 percent. Further increases in applied heat gave anomolous figures of more than 100 per cent oxidation. Different degrees of heat even resulted in differing values for the so-called "blank" with distilled water.

Results are presented of tests on dairy products, caustic oil refinery wastes, and soap manufacture wastes, and it is concluded that the method can be used to give approximate values of the total pollution. D. A. OKUN

Nutritional Requirements in the Biological Stabilization of Industrial Wastes. II. Treatment with Domestic Sewage. By E. N. HELMERS, J. D. FRAME, A. E. GREENBERG, AND C. N. SAWYER. Pp. 375–395.

This paper was published in THIS JOURNAL, 23, 7, 884 (July, 1951).

Chlorination of Phenol-Bearing Rubber Wastes. By W. D. SECHRIST AND N. S. CHAMBERLAIN. Pp. 396–412.

Scrap tires are the major source of reclaim rubber. The first step in the process involves cracking or comminuting the scrap, screening, further cracking of coarse particles, and demetalization. Any of three processes may be used in reclaiming the processed scrap rubber—acid process; heater, pan, or open steam process; and digester process. Most of the waste (70 per cent) is produced in the acid process and consists of acid water from the washing trough, neutralizing tank, and squeezer. The second process produces a condensate waste, which is highly contaminated with gums, resins, etc., and constitutes approximately 5 per cent of the total volume of wastes to be treated. It is similar in composition to the digester process wastes. The digester process alkali and chloride waste liquors constitute approximately 25 per cent of the total volume of wastes, are highly concentrated, and are most difficult to treat because a considerable portion of the plasticizer residues present are phenol-bearing. Typical analyses of the three types of wastes are given. The chemicals most frequently found in the wastes are typical of such groups as the monobasic carboxylic acids, polybasic acids, derivatives of carbonic acid, hydro-aromatic compounds (terpenes), and phenols, in addition to alkali and hydrocellulose. Preliminary studies showed that separation of the acid and alkali wastes would be desirable and that a pilot plant including coagulation, settling, and chlorination would be required. From the results of the pilot plant study it can be concluded that the best treatment is pretreatment with copperas (50 to 100 gr. per gal.) and settling, followed by chlorination (sufficient to give an excess chlorine residual of 100 to 500 p.p.m.) with a subsequent settling or retention time of from 3 to 5 hr. This insured a clarified phenol-free effluent having the lowest possible color and odor characteristics. The addition of copperas in secondary treatment may, at times, be desirable. The pH of the chlorinated waste should be adjusted and controlled automatically, principally with lime. A complete description and flow sheet of the waste disposal facilities under construction is given. It is estimated that the wastes may be treated for $1.66 per 1,000 gal. based on a chlorine demand of 2,000 p.p.m. and raw materials at current market prices.

The Design and Operation of a Waste Treatment Plant for a Small Packing Plant. By ALLAN H. WYMORE. Pp. 413–420.

A new plant for treating slaughtering and meat processing wastes at the Reitz Meat Products Co., Raytown, Mo., is described. It was designed for two-stage filtration with recirculation and primary and secondary clarification. The primary and secondary clarifiers are combined in one "Duo"-unit. The same is true of the primary and secondary filters. A heated digester of the conventional clarigester design is included, as are conventional sludge drying beds. Basic design data are as follows: design flow, 83 g.p.m. during an 8-hr. day; design kill, 36 cattle or 120 hogs per day; assumed B.O.D., 582 lb. per day; clarifier overflow rate,

1,170 g.p.d. per sq. ft.; filter dosing rates, primary 13 m.g.a.d., secondary 20 m.g.a.d.; and digester volume, 5,544 cu. ft. Sampling data show that the 5-day B.O.D. of the raw sewage varied from 350 to 1,480 p.p.m., suspended solids from 358 to 5,400 p.p.m., total nitrogen from 40 to 100 p.p.m., nitrate nitrogen from 0.34 to 2.0 p.p.m., nitrite nitrogen from 0.006 to 0.02 p.p.m., and chemical oxygen consumed (3 tests) from 956 to 4,480 p.p.m. Average influent B.O.D. is reported as 744 p.p.m., primary effluent B.O.D. as 246 p.p.m., for a removal of 67 per cent. Average flow for 6 days was 26.6 g.p.m., or 32 per cent of the design flow. Recirculation rates were 8.4 to 1 or 3.8 to 1, depending on the pumping arrangement. A reported over-all B.O.D. removal of 82 per cent is said to be low. A single day's analysis giving a 96 per cent over-all B.O.D. removal is stated to be more typical than the other. Filter ponding is indicated and it is believed that grease removal facilities throughout the plant would obviate this difficulty. The cost of the plant is given as $50,000.

Purification of Wastes in a Metalworking Plant by Lagooning. By Charles R. Griffith. Pp. 421–433.

A 15-acre lagoon of approx. 5-m.g. capacity has been in operation for 5 yr. as a unit of a waste disposal system at the Salisbury Axle Plant, Ft. Wayne, Ind. All plant wastes, including soaps and alkaline cleaners, acid cleaners, mineral and emulsified oils, solvent emulsions, paint, boiler compounds, and acid coal pile drainage flow through the soap lines (process sewer) to the first detention basin. Flows vary from 100 to 150 g.p.m. during plant operation. The first basin provides 2-day detention time (theoretical), during which sedimentation takes place and much of the oil separates and floats to the surface. Influent oil has shown readings between 735 and 1,800 p.p.m. and the effluent averages 144 p.p.m. The effluent from the first basin discharges into the second detention basin (the 15-acre lagoon), which provides a detention time of approximately 25 days. Average results of a 10-month period in 1950 show reductions in 5-day B.O.D., suspended solids, and oil of 93.4, 83.1 and 95.2 per cent, respectively, after passage through the lagoon. The effluent showed an average dissolved oxygen content of 3.6 p.p.m. The inherent advantages reported for this particular application of lagooning are low operating costs, low initial cost, high efficiency, and flexibility. The disadvantages are space requirement, low dissolved oxygen content, and lack of knowledge as to the phenomenon taking place in the lagoon and responsible for its action.

Conrad P. Straub

De-Inking Waste Treatment Plants at Plainwell, Michigan, and Fitchburg, Massachusetts. By A. J. Palladino and J. F. Baigas. Pp. 434–440.

This paper describes two de-inking waste treatment plants and their operation. Processes for the treatment of de-inking wastes are directed toward the reduction of suspended solids and B.O.D. A typical analysis of a de-inking waste shows 4,500 p.p.m. solids with 50 per cent volatile content, 2,800 p.p.m. suspended solids with 40 per cent volatile content, 600 p.p.m. B.O.D., pH 9.8, and a total waste flow of 25,000 gal. per ton of pulp produced.

The first plant described is a primary treatment plant consisting of a 40-ft. diameter by 10-ft. deep clarifier and a 300-sq. ft. vacuum filter. The theoretical detention time in the clarifier is 2.5 hr.

Operating data show removals as follows: suspended solids, 53 per cent; volatile suspended solids, 67 per cent; and B.O.D., 7 per cent.

The second plant is a demonstration unit for biological aeration of the de-inking waste (see This Journal, **23**, 11, 1419, Nov., 1951).

Interesting Developments in Industrial Waste Disposal. By L. F. Warrick. Pp. 441–454.

This paper describes briefly certain developments in the solution of industrial waste problems. The importance of extensive research and development work to accomplish essential results in waste utilization and stream improvement is emphasized, as this is one of the main objectives of the recently established National Technical Task Committee in Industrial Wastes. The author discusses the role of governmental, as well as private agencies, in the control of stream pollution.

Blitz on Insects Creates Water Problems. By L. F. Warrick. Pp. 455–463.

During August, 1950, the reported deaths of fish in the cotton-growing areas of northern Alabama caused investigations to be made by the Alabama State Board of Health, the Alabama Water Improvement Advisory Committee, and the U. S. Public Health Service. They indicated the probability that insecticides washed from the soil into the streams by heavy rains were responsible for the wholesale deaths of both game and rough fish species in these streams.

The variety of insecticides used is described. The most popular was a dust containing 20 per cent of toxaphene, to which 40 per cent of sulfur was added in some formulations. Throughout the Alabama portion of the Tennessee Valley toxaphene constituted 61 per cent of the total amount of the insecticide applied; 34 per cent consisted of the benzene hexachloride-DDT mixture; 4 per cent contained aldrin; and 1 per cent was calcium arsenate or others.

Toxaphene is indicated to be by far the most toxic to fishes, one writer going so far as to suggest that toxaphene be used as a fish poison in fish management work. Considerable data are given in the paper concerning the toxicity of the various insecticide components. D. A. Okun

Strawboard Lagoon Operation at Noblesville, Indiana. By Carl G. Kraucher. Pp. 464–478.

Lagoons for this plant, cooking 120 tons of wheat straw daily, have been in operation nearly 50 years and at present cover 147 acres and have a capacity of 47,000,000 cu. ft. Flow is in series through four units, the fifth being used for emergency storage.

Lagoon effluent is discharged to White River at a fixed dilution ratio of 1 to 350. To maintain this, lagoon discharge is measured by a recording gage over a weir and matched against river flow, which is obtained hourly from stream levels and charts. A valved outlet from the lagoons feeds the weir box. Color, D.O., and B.O.D. checks are made periodically of the river and lagoon effluent.

A weir is also set up at the inlet to the lagoons and samples are collected hourly. A table shows average flow, total solids, 5-day B.O.D., color, and pH of influent and effluent. Monthly averages show that with influent B.O.D. ranging from 800 to 1,440 p.p.m., reductions of 20 to 73 per cent were obtained. An average of more than 1 m.g.d. is discharged. Sludge is dredged out, dried, and used as a low-grade fertilizer.

The Treatment of Food Processing Wastes. By R. J. Dougherty. Pp. 479–506.

Results of tests over a 4-month period on a chemical precipitation plant for cannery wastes are tabulated and show 9 to 82 per cent B.O.D. removal, the average being 47.4 per cent. Ferric salts or aluminate and lime were used, the dosage not being clearly given, but the cost of treatment was approximately $150 per m.g.

Results of three months of studies on digestion of apple wastes, with 7-day detention at 97° F. show that with a raw B.O.D. averaging 980 p.p.m., a 75 per cent reduction can be obtained. The effluent had a strong odor and attempts to improve it by aeration failed. Similar results were obtained on digestion of tomato wastes.

A pilot plant with capacity of 1 to 2 g.p.m. was constructed on the principle of accelerated activated sludge. The system consists of 10 to 15 min. aeration, clarification, and 2-hr. aeration of the sludge, which is then returned to the influent. Results for apple, tomato, and peach wastes showed average reductions of 62 per cent B.O.D., 67 per cent suspended solids, and 72 per cent oxygen consumed. Color removal was nearly complete. The pilot plant was found simple to operate and control and a larger one is planned. W. Hasfurther

Determination of Oxygen-Consumed Values of Organic Wastes—A Comparative Study of Methods. By W. Allen More, F. J. Ludzack, and C. C. Ruchhoft. *Anal. Chem.*, 23, 1297 (1951).

Because of the need for a rapid chemical procedure to aid in defining the strength of organic industrial wastes, several people have recently published techniques which would yield an approximation of the total organic matter content. One of the methods which was never completely published uses the iodate ion as the source of oxidant. In comparison with the other methods, this technique is time consuming and requires considerable complex apparatus. The results with the iodate were not enough

better to justify the added time and equipment used. Each of the other new techniques uses the dichromate ion under very rigorous conditions of high acid concentration and temperature. One technique evaporates off all the water and carries out the oxidation at very high temperatures for only a few minutes. This technique requires a high degree of skill for best results and even these do not compare favorably on a statistical basis with the other two methods, which use refluxing at 145°C. for a longer period of time (30 to 120 min.), depending upon the nature of the sample. This temperature is attained in one technique with plain sulfuric acid and an equal volume of water, the sum of the sample plus the standard dichromate; whereas in the second method, the sample is only two-fifths of the acid volume because phosphoric acid is used to reduce bumping during digestion. Pumice is used to reduce bumping with plain sulfuric acid. The use of plain sulfuric acid and a larger relative volume of sample aids in the over-all reproducibility of the results and makes possible the use of more dilute samples directly. The use of a trace of silver sulfate as a catalyst is possible with plain sulfuric acid and increases the accuracy of this technique for oxidizing alifatic organic compounds.

The authors of this article claim that the end point obtained by using ferrous sulfate for backtitrating the excess dichromate is sharper than can be obtained when iodine with thiosulfate is used for the back titration. A very sensitive ferrous ion indicator causes a sharp change in hue that is more easily seen than the disappearance of blue in a green background of the chromic ion.

On the basis of the work reported in this article, the Standard Methods Committee of this Federation has chosen the oxygen consumed technique using dichromate with sulfuric acid refluxed at 145°C. for 2 hr. as the new procedure for the 10th Edition of "Standard Methods."

R. S. Ingols

Gulf Coast Regional Conference on Industrial Health. Anon. *Chem. Eng. News*, **29**, 4262 (1951).

The industrial waste disposal sessions have become an outstanding part of the Gulf Coast Regional Conferences. L. A. Danse, of General Motors, indicated that the job of industrial wastes must be handled by industry and not by the government. The treatment of cyanide wastes in alkaline solutions was described by Synder. Hexavalent chromium may be reduced with sulfur dioxide and the trivalent chromium precipitated.

C. F. Renn described a method for the determination of tolerances of various compounds in industrial wastes toward fish. He suggested the use of barnacles for the study of industrial waste discharge into sea water.

The capacity of trickling filters to handle aldehyde polymer and condensation wastes was again presented. Reductions in B.O.D. from 12,000 to 30 p.p.m. were reported. These results were obtained on the Celanese Corp. plant at Bishop, Tex., by J. L. Regan.

R. S. Ingols

Gravesend Sewage Disposal Works Extensions. By R. F. Long. *Surveyor*, **110**, 645 (Oct. 13, 1951).

Results obtained at the disposal works at Denton, Gravesend, England, are presently unsatisfactory. The difficulties arise mainly from lack of grit removal and insufficient capacity for purification. The present plant provides for sedimentation of up to 3.3 m.g.d. (Imp.) (3x D.W.F.), and activated sludge treatment of 480,000 g.p.d. (Imp.). Storm-water overflows are settled and discharged. Waste activated sludge is intermittently returned to the raw sewage. Primary sludge is digested in two stages, providing for a total retention of 56 days, followed by air drying.

The proposed additions include new grit channels and screen chambers, additional aeration channels, and a new influent line. It is planned that full secondary treatment of flows up to 2.64 m.g.d. will be possible when the new construction is completed. The existing primary and secondary sedimentation tanks will be used in the new system. Despite the increased flow, the primary tanks will provide a detention period of 4.1 hr. at dry-weather flow. Detention time in the secondary tanks is not stated, but the maximum upward velocity will be 3.14 ft. per hr. Provisions will also be made for continuous removal of waste sludge, for gas storage, and for new aeration channels.

M. C. Rand

Determination of Nitrite Plus Nitrate in Sewage, Sewage Effluents, and River Water. By S. H. Jenkins. *Jour. and Proc.*, Inst. Sew. Purif., Part 2, p. 145 (1950).

The distillation residue from the ammonia nitrogen determination is saved and the oxidizable compounds of nitrogen are reduced by boiling with Devarda alloy. The ammonia so produced is distilled over and determined by the titration method described in the previous paper. When the nitrate content is required separately, the nitrite is determined colorimetrically by the beta naphthol and sodium naphthionate method, and the result deducted from the total oxidized nitrogen.

K. W. Cosens

The 'A-G' Sewage Conversion Process. Anon. *Water & San. Eng.*, **2**, 6, 222 (Oct., 1951).

This is nothing more than the commercial exploitation of well-known processes. The sludge is digested under controlled conditions of heating, circulation, etc., for the utilization of the gas produced. The digested sludge is then mixed with refuse and composited for the production of humus for agricultural purposes.

H. Heukelekian

Summary Report on Water Pollution: Great Basin Drainage Basin. U. S. Public Health Service Publ. No. 82 (1951).

This third in a series of summary reports on major drainage basins of the United States points out that sewage and waste treatment projects are needed at 150 municipal and industrial locations in the Great Basin, which includes portions of five states.

The 150 sewage and wastes treatment projects needed in the basin include 92 for municipalities (many handling industrial as well as domestic wastes) and 58 for industries. Municipalities need 58 new treatment plants, enlargements or additions to 19, and replacement of 15 plants. Industry needs 43 new plants and enlargements or additions to 15. A total of 142 municipalities, institutions, and sanitary districts discharge sewage equivalent to a population of 623,620, including industrial wastes discharged through public sewer systems.

Of the 137 known separate industrial waste outlets in the basin, 95 produce organic wastes having a population equivalent of 1,201,105, 11 produce organic wastes for which the population is undetermined, 24 produce inorganic wastes, and 7 produce wastes of undetermined type.

No projects are needed at 46 municipal and 28 industrial locations, but project needs are undetermined for 4 municipalities and 77 industries.

Initial costs of required municipal treatment plants in the basin is estimated at $9,315,000. No cost estimate is given for industrial waste treatment needs because of the scanty information available on this phase.

H. P. Orland

Discussion on Trade Waste (Tannery) Purification Plant. By W. Foster. *Jour. and Proc.*, Inst. Sew. Purif., Part 2, p. 98 (1950).

A description is given of a chrome tannery treatment plant in Scotland with a daily volume of 65,000 gal. including 16,000 gal. (Imperial) of sulfide liquors from the liming process. The sulfide liquors were treated by aeration and the addition of copperas and then added to the main plant waste after the latter had been settled for 8.25 hr. This treated material was then discharged to the city sewers for further treatment with the sewage. Treatment results of the mixed effluent are given, as follows:

	Before Treatment (p.p.m.)	After Treatment (p.p.m.)
Ammonia N	120	38
Albuminoid N	190	13.9
B.O.D.	600	320
Sulfides	480	46.3
Fats	46	18
Susp. solids	7184	448

K. W. Cosens

Vitamin B_{12} in Activated Sewage Sludge. By Sam R. Hoover, Lenore B. Jasewicz, and Nandor Porges. *Science*, **114**, 213 (Aug. 24, 1951).

The apparent vitamin B_{12} content of aerator sludge from a municipal sewage treatment plant, shown by direct assay with *Lactobacillus leichmannii* ATCC 4797, was determined essentially by the method of Skeggs *et al.* Because this type of

sludge might contain almost any product of animal or vegetable metabolism, it was tested further by alkaline destruction of vitamin B_{12} and chromatographic separation on paper from other materials stimulating growth of the test organism. The amount of vitamin B_{12} indicated by the alkaline destruction procedure was about that shown by chromatographic separation. The alkaline destruction method is indicated as a satisfactory measure of vitamin B_{12} activity of the sludge preparations for *L. leichmannii*.

A vitamin B_{12} content of 1.5 m.g. per lb. (3.3μg. per g.) has been proposed by the Association of American Feed Control Officials as a required level for commercial feed supplement. Considering minimum values, the amount of B_{12} in the samples dried under mild conditions was well above that required. A commercially available dried sludge contains similar significant amounts of B_{12}.

Existence of the large potential supply of B_{12} in activated sludge is economically important, as heretofore dried sludge has been of value only as a fertilizer.

H. P. ORLAND

Cemeteries as Sources of Water Pollution. By F. W. J. VAN HAAREN. *Water* (Neth.), **35**, 167 (Aug. 2, 1951).

In a sandy soil about 10 yr. are required to oxidize a corpse. During decomposition breakdown products leach out. Results of analyses of surface and ground waters of a number of cemeteries show that in every case these waters were heavily polluted.

W. RUDOLFS

A Report on Sewage Treatment Practice Based on an Overseas Tour—July–November, 1949. By J. B. ROWNTREE. Auckland (New Zealand) Metropolitan Drainage Board. 51 pp. (1950).

Modern trends in methods of treatment of sewage and industrial wastes based on practice in the United States, Canada, Great Britain, Eire, Netherlands, and Australia are discussed, together with the suitability of the methods for conditions in Auckland. Included in the subjects specifically covered are screening; grit removal; pre-aeration; mechanical flocculation; sedimentation; high-rate filtration; activated sludge process; methods of aeration; oxidation ponds; sewer outfalls; treatment and disposal of sludge by digestion, on drying beds, in lagoons, by vacuum filtration, by the Porteous process, by incineration, and as fertilizer; utilization of sludge and garbage in composts; and standards of effluent quality as related to pollution of surface waters.

H. P. ORLAND

Metropolitan Water, Sewerage and Drainage Board, Sydney, Australia. Annual Report for Year Ended June 30, 1951. 50 pp.

The Board serves an estimated population of 1,870,000 on an area of 3,993 sq. mi., having jurisdiction over water supply and sewers. Sydney and its suburbs are served by three major sewer systems, which discharge to the Pacific Ocean without treatment, and five minor systems, of which three discharge to the ocean and two are served by local treatment works. Ocean outfalls are in deep water, 30 ft. below high-water level. Primary treatment is being installed on one of the ocean outfalls to eliminate possible pollution of bathing beaches. Financial statistics and general maps are provided.

LANGDON PEARSE

A Rapid Method of Estimation of Ammonia Nitrogen in Sewages and Effluents. ANON. *Analyst*, **74**, 882, 511 (Sept., 1949).

The Ministry of Health (British) prefer to estimate ammonia nitrogen by distillation; the American Public Health Association, by direct controlled Nesslerization. The British Nesslerization method is not entirely satisfactory. The authors point out that when sodium hydroxide is used to clarify samples the yellow color due to Nessler solution is progressively deepened by increasing amounts of sodium hydroxide.

The authors recommend the use of sodium hexametaphosphate (Calgon) for clarification in place of sodium hydroxide in the direct Nesslerization method and present experimental data to show comparable results of analyses on sewage and sewage plant effluents using the Calgon method and the distillation methods. The method has limitations when tidal river waters are encountered.

KENNETH W. COSENS

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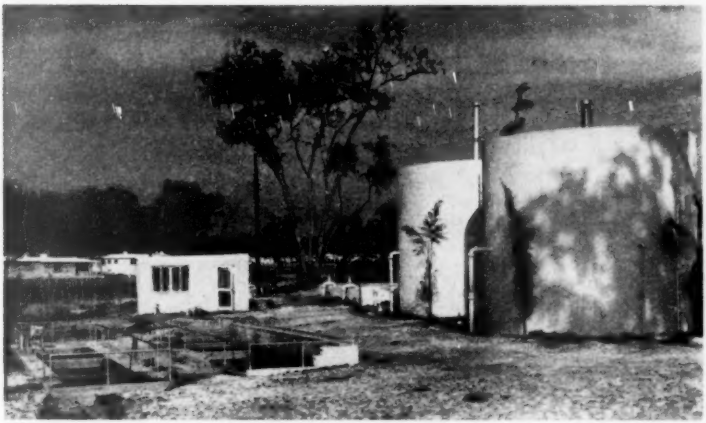

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Proceedings of Member Associations

ARIZONA SEWAGE AND WATER WORKS ASSOCIATION

The 1952 Annual Meeting of the Arizona Sewage and Water Works Association was held at Mesa, Ariz., April 3–5, 1952. Some 175 persons registered for the meeting.

Papers presented at the technical sessions included:

"Venturi Meters," by C. G. Richardson, Vice-President, Builders-Providence, Inc., Providence, R. I.

"Control Instrumentation," by Emery Ferree, Minneapolis-Honeywell Regulator Co.

"Mobilized Sewer Cleaning," a motion picture by Ace Pipe Cleaning Contractors, Inc., Kansas City, Mo.

"Measurements in Flow Line," by Richard Bennett, Hydraulic Engineer, City of Phoenix.

"Simple Hydraulics for Operators," by John Schaefer, Civil Engineer, Yost and Gardner, Consulting Engineers, Phoenix.

"Twenty-Five Years of Progress," by Earnest Boyce, President, FSIWA.

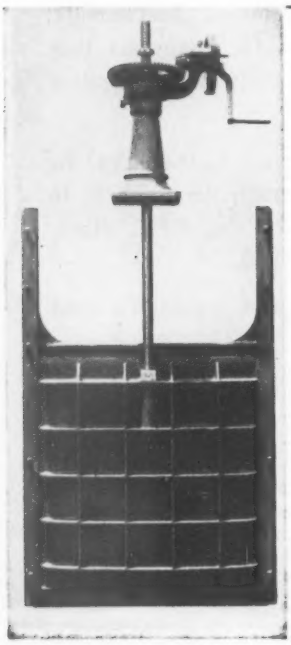
"High-Rate Water and Sewage Treatment," by A. A. Kalinske, Research Engineer, Infilco, Inc.

"Review of Chlorination," by Otto Bejcek, Sales Engineer, Wallace and Tiernan Co.

"Western and Eastern Sewages," by Fred G. Nelson, Manager, Western Sanitary Division, The Dorr Co.

The usual "Operators' Round-Up," or open forum discussion of opera-

(Continued on page 286a)



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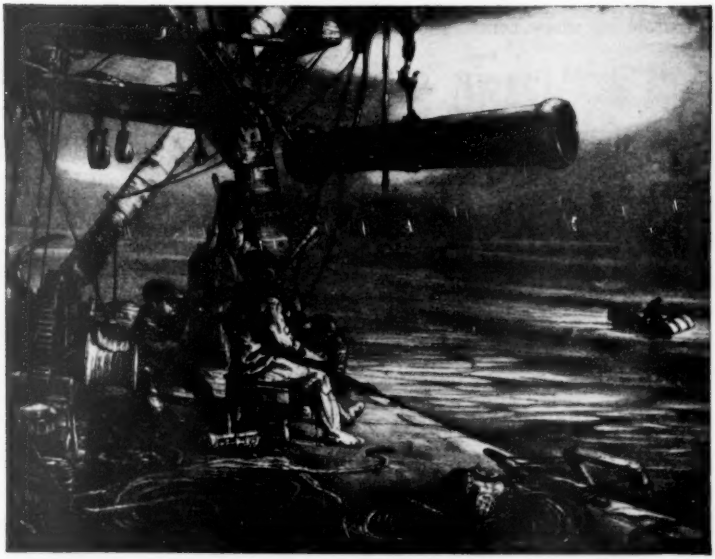

"Dressing The Diver," lithographed on stone for U.S. Pipe and Foundry Co. by John A. Noble, A.N.A.

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1st Vice-President: W. Harford, Phoenix.
2nd Vice-President: R. G. Baker, Phoenix.
FSIWA Director: L. O. Gardner, Phoenix.
Secretary-Treasurer: M. V. Ellis, Phoenix.

M. V. Ellis,
Secretary-Treasurer

FLORIDA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 1951 Annual Meeting of the Florida Sewage and Industrial Wastes Association was held jointly with the Florida Section, AWWA, at the Sheraton Plaza Hotel, Daytona Beach, Fla., October 28–31, 1951. Registration of members and guests totaled 256.

Papers of interest to sewage and industrial wastes personnel included:

"Corrosion in Water and Sewage Plants," a panel discussion covering sulfur corrosion, cathodic protection, and corrosion prevention research, by A. H. Gropp, Chemistry Dept., Univ. of Florida; F. P. MacDonald, Electro Rust-Proofing Corp., Belleville, N. J.; and A. Kimmel, Asst. Professor of Chemical Engineering, Univ. of Florida.

"One Year's Operation of the Orlando Biofiltration Sewage Treatment Plant," by M. S. Nagel, Superintendent of Sewage Treatment, Orlando.

"Four Year's Work at the Sanitary Research Laboratory of the University of Florida," by W. T. Calaway and T. S. Furman, Sanitary Engineering Dept., Univ. of Florida.

"Materials Allocations," by T. T.

(*Continued on page 288a*)

A TWO-STAGE SPIRAFLO CLARIFIER AERO-FILTER INSTALLATION AT THE SEATTLE-TACOMA AIRPORT

The primary and final Spiraflos are 13 ft. in diameter. The two 18-ft. diameter Aero-filters have motor driven discs. The Intermediate clarifier is rectangular with a hoppered bottom.

The surface rates in the clarifiers average approximately 1000 gal. per sq. ft. per 24 hr. The detention period is less than 2 hr.

	Average Removals (%)	
	Suspended Solids	B. O. D.
By primary clarifier	82.8	74.8
By entire plant	96.8	96.7

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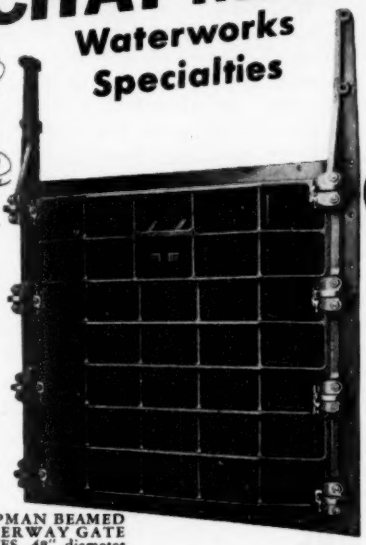

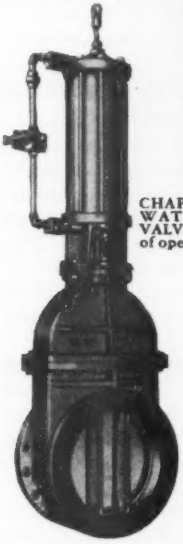

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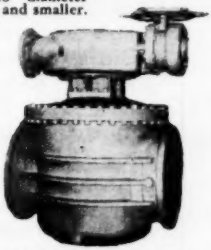

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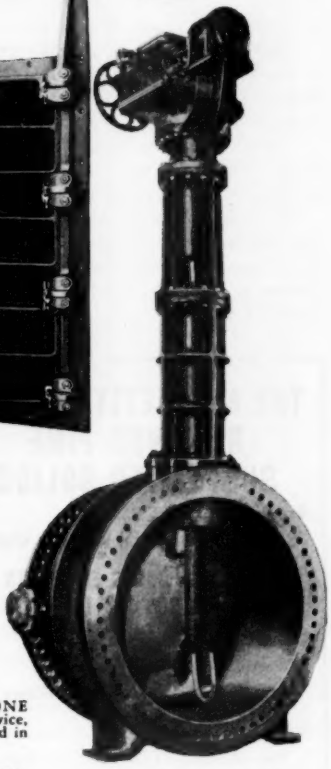

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"Progress in the Phosphate Waste Problem Study," a panel discussion from the viewpoints of research, industry, and the state regulatory body.

"A Review of Citrus Waste Treatment Methods," by John W. Wakefield, Florida State Board of Health.

"The Maintenance of Sewage Treatment Plant," by R. E. Fuhrman, Superintendent, District of Columbia sewage treatment plant, Washington, D. C.

"Safety Practices in Water and Sewage Plants," by A. P. McIntosh, Safety Consultant, Florida Industrial Commission, Tallahassee.

"Municipal Consultant's Service," by T. Wainwright, Municipal Consultant, New York, N. Y.

"Stream Pollution Control in Florida and Neighboring States," a discussion by a panel representing Florida, Alabama, Georgia, South Carolina, and U.S.P.H.S.

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The meeting concluded with an inspection trip to the Daytona Beach water and sewage treatment plants.

Several Club Room periods, sponsored by members of the Water and Sewage Works Manufacturers Association, provided informal opportunities for getting acquainted. Other social highlights of the meeting included the Fish Fry and Beer Party on October 29, courtesy of the City of Daytona Beach and held on the world-famous ocean beach, and the Annual Banquet and Dance on October 30.

Officers elected for 1951–52 were:

President: J. E. Kiker, Jr., Gainesville.
Vice-President: J. W. Wakefield, Jacksonville.
Secretary-Treasurer: P. M. Teeple, Jacksonville.

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TEXAS WATER AND SEWAGE WORKS ASSOCIATION

The 1952 Annual Meeting of the Texas Water and Sewage Works Association, held in conjunction with the 34th Annual Short School at Texas A. & M. College, College Station, Tex., March 9–13, 1952, for the fourth consecutive year set an all-time record attendance. Registration for the meeting totaled 625.

In addition to a comprehensive program for both water and sewage works personnel, the Short School featured an Industrial Wastes Symposium occupying an entire day, and several papers on administrative matters.

The following officers were elected to serve the Sewage and Industrial Wastes Section during 1952–53:

Chairman: A. H. Ullrich, Austin.
Vice-Chairman: A. C. Bryan, Houston.
Secretary: V. M. Ehlers, Austin.
Assistant Secretary-Treasurer: Mrs. Earl H. Goodwin, Austin.

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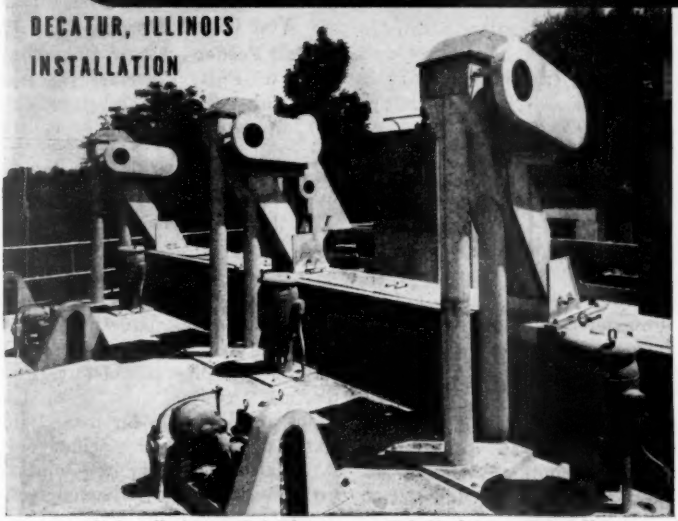

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- Elevator is separate, independently-operating mechanism, with greater capacity than the collector.
- Drag mechanism is kept free . . . never overloaded.
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Flow Signal Transmitter—Bulletin 2551 describes flow and pressure uses of a new signal transmitter for uses with static pressure up to 1,500 lb. per sq. in.—Hagan Corp., P. O. Box 1346, Pittsburgh 30, Pa.

Clay Liner Plates—A new 6-page brochure gives a wealth of information with graphic drawings and tables on use of vitrified clay liner plates for cast-in-place and pre-cast sewers.—Universal Sewer Pipe Corp., 1500 Union Commerce Bldg., Cleveland 14, Ohio.

Plunger Sludge Pumps—New Bulletin No. 5102 includes detailed information, engineering data, and specifications on a complete series of plunger sludge pumps. Pump and motor selection charts, specifications, lubrication data, and essential data on diaphragm pumps for general duty make this bulletin a valuable reference.—Ralph B. Carter Co., 224 Atlantic St., Hackensack, N. J.

Floor Gratings—Detailed data for a complete line of walkway, stair, roadway, and floor armoring grating of several types are given in a new brochure. Items can be secured in mild steel, aluminum, bronze, stainless steel, monel metal, etc.—Irving Subway Grating Co., Inc., 50-05 27th St., Long Island City 1, N. Y.

Concrete Sewers—A new 48-page booklet (C-10) entitled "Concrete Sewers" contains a number of tables and charts packed with valuable information on the design and construction of concrete sewer systems. The material includes the latest available research data covering loads on sewer conduits. Among the topics covered are the hydraulics and construction of sewers, types and design of sewer systems, maintenance and repair of sewer lines, and safety precautions in sewer operations.—Portland Cement Assn., 33 West Grand Ave., Chicago 10, Ill.

Belt Feeder—A new 4-page bulletin (No. 35-F5B) describes the installation and operation of a belt gravimetric feeder making possible continuous weighing and feeding of dry materials at capacities from 100 to 100,000 lb. per hr.—Omega Machine Co., 345 Harris Ave., Providence, R. I.

Screw-Seal Pipe—Industrial vitrified clay pipe joined by screwed plastic couplings is a recent development described in a new bulletin. Known as "Screw-Seal," the threaded joint is cast on the pipe barrel during manufacture. Special split union connections are available for inaccessible locations. The usual vitrified clay fittings also are available. Joints made by this method are claimed to be infiltration-proof and root-proof.—Robinson Clay Product Co., Akron 9, Ohio.

Bellows Connector—A new booklet describes Teflon bellows-type pipe connector to combat vibration, expansion, electrolysis, and corrosive liquids and gases.—Crane Packing Co., Dept. R7, 1800 Cuyler Ave., Chicago, Ill.

pH Meter—A new universal pH meter has been announced providing pH range of 0 to 14.15 with measuring accuracy of 0.01 pH. Different types of electrodes may be used.—North American Philips Co., Inc., 750 S. Fulton Ave., Mount Vernon, N. Y.

Laboratory Dryer—A new portable laboratory dryer incorporating the latest features of design and precise control of temperature and circulation has been announced.—Denver Equipment Co., 1400 17th St., Denver, Colo.

New Plant at Fond du Lac...

combines refuse incineration and sludge disposal

A large part of the heat requirements at the new sludge drying plant at Fond du Lac, Wisconsin will be provided by a refuse incinerator. This combination arrangement is typical of the trend in smaller installations and effects considerable fuel savings.

Fond du Lac Plant, which went into operation in September of 1951 will serve an equivalent population of 75,500. It is equipped with a C-E Raymond Flash Dryer Unit designed to handle 15½ tons of filter cake per day, with an evaporation rate of 2,600 pounds per hour. Although the plant is located a short distance from a public park, the use of high temperature deodorization has completely eliminated objectionable odors.

The C-E installation at Fond du Lac is typical of C-E Raymond Systems now in service in virtually all parts of the country, meeting the varying requirements of both large and small communities. They are flexible in layout, highly efficient and thoroughly reliable; they provide for maximum utilization of waste heat.

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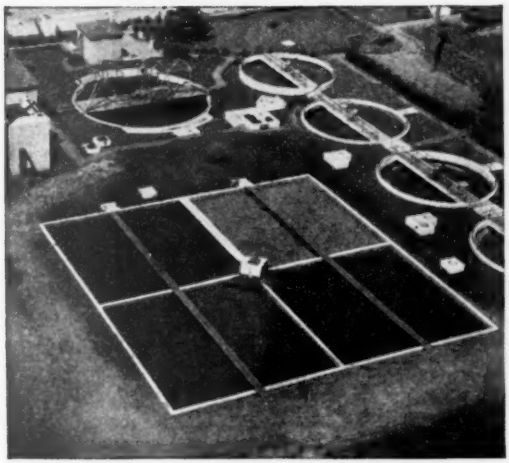

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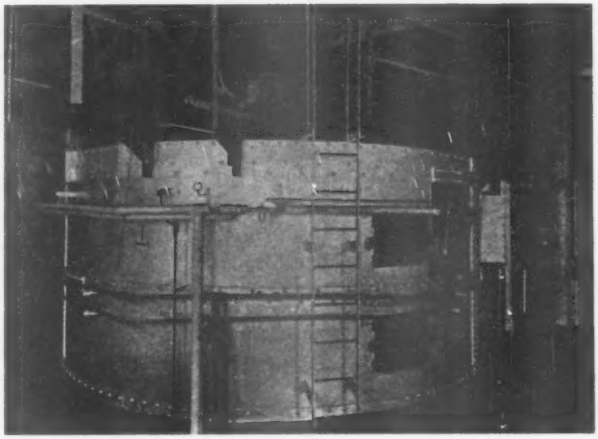

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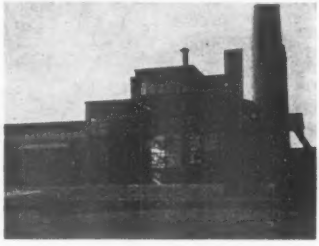

Above: Exterior view of the Bridgeport, East, Plant

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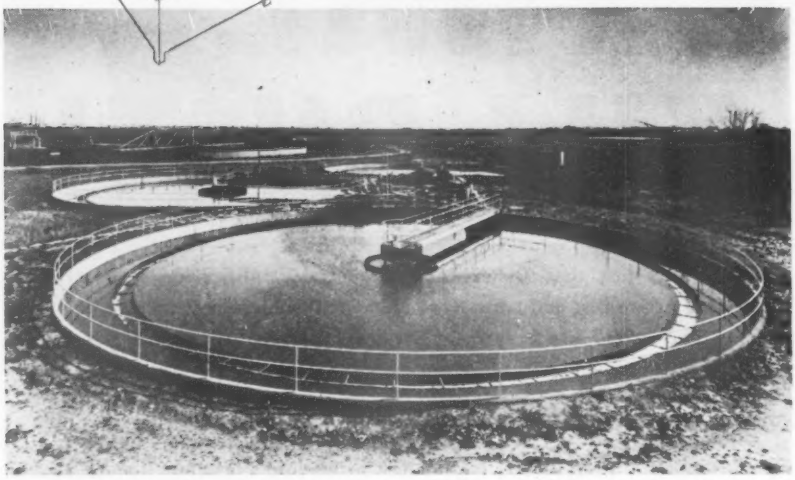

EARLY IN 1950 the city of Stockton, California, in order to double the secondary sedimentation capacity of their South Stockton Sewage Treatment Plant, added a 100 ft. dia. sedimentation tank equipped with a Process Type C Clarifier mechanism. One year later, in 1951, a third 100 ft. dia. sedimentation tank was erected and again equipped with a Process Type C Clarifier mechanism. The Type C has a center column that supports the drive unit and one end of the stationary walkway.

The picture above shows in the immediate foreground and the far background the two Process Clarifiers. In the background may also be seen one of the 166 ft. dia. biological filters equipped with a Pacific Flush Tank Company Rotary Distributor. Each of these rotary distributors has a total capacity of from 2300 to 7000 gpm.

Consulting engineer for the installation of the new Process Clarifier was the Engineering Office of Clyde C. Kennedy. Contractor: Fred J. Early Jr. Co., Inc. Plant operation is under the direction of F. Wayland Jones.

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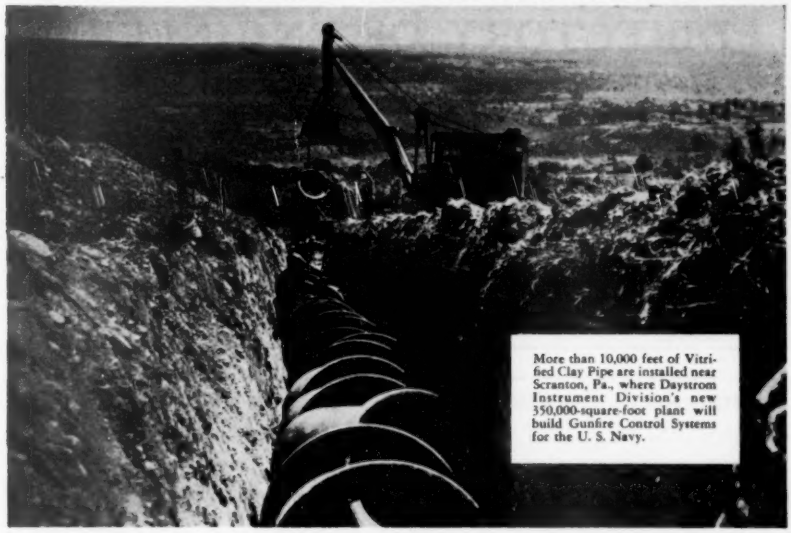

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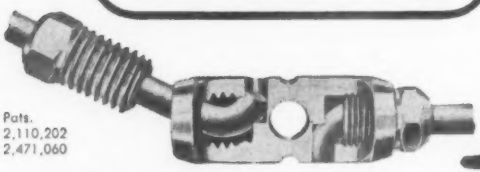

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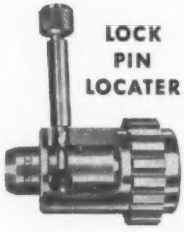

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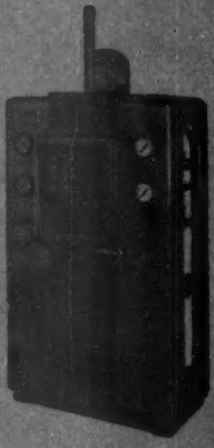

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